Development of a Comprehensive Software for Environmental Engineering Practice and Education

A Thesis Submitted in Partial
Fulfillment of the
Requirements for the Degree
of Master of Technology

by

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to the

Environmental Engineering
Department of Civil Engineering
Indian Institute of Technology Kanpur

May, 1998

Certificate

It is to certify that the work contained in the thesis titled *Development of a Comprehensive Software for Environmental Engineering Practice and Education* by Ravi Shankar has been carried out under my supervision.

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May, 1998

Acknowledgements

It is indeed an experience to remember. Since last two years the life at IIT Kanpur has never been easy, neither it was meaningless. It is more important due to the training of life and life like situations in comparison to academic activities and achievements. I learnt here the patience, tolerance, ability to cope the pressure and to adjust myself to difficult conditions and make some good friends. The last two years may not be the best of my academic life, but certainly it carries considerable importance in my social and personal life. I wish to thank and express my deep regards to Dr Vinod Tare, my thesis supervisor, who has thoroughly conducted himself as a trainer for my overall development. His support during crisis and complete faith on me are some of the things, which I will never forget

I will be accused of injustice, if I don't appreciate the help and support provided by Nitin during my thesis preparation. He was always ready to help me whenever required. His friendship is one of the few things, which I will remember throughout my life. I do acknowledge the help by Nita and Ajay Gupta during my thesis work. I am sincerely thankful to them from inner core of my heart. Akshay Nandan and Parma Nand Jha also deserve special thanks for their ready help whenever I approached them.

Thanks are due to Dr Malay Chaudhuri and Dr C. Venkobachar for their teaching, which to some extent, made me acquainted with fundamentals of environmental engineering.

I am fortunate to have some good friends at IIT Kanpur. In fact it was their support, inspiration and love that made my stay memorable here. Prashant, Mukesh, Arti, Parmanad Jha, Jaiswal and all other BITians deserve my thanks for the help, love and affection, which I certainly didn't deserve much. In their company I always relaxed from the tension of work and enjoyed most.

It will be too formal to say that I have had wonderful batchmates. Their nice behavior, cooperative nature and concern for me, these are some of the things I will never forget in my life. I enjoyed partying, discussing any problem or even fighting with them for small reasons. Being a typical ***Bihari*** certainly helped me to laugh and make others laugh. I fondly remember Manish, Saurabhi, Rajeswari, Vishnu, Santosh, Rohit, Aparna and Capt. Sanjeev Bajpai and his Family for the nice time spent with them. I would also like to thank Kanchan for her willingness to help me during my thesis.

Vijay jee and other staff members of lab deserve my thanks for their concern and creating enjoyable environment in the lab.

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cc	Circumferential Circular Clarifier
cd	Condensation
ch	Hoods for Cold Processes
cl	Chlorination
cp	Cyclone Chambers
crc	Circular Radial Clarifier
d	Duct
da	Diffused Aeration System
ds	Dry Scrubbers
e	Equalization Chamber
er	Expanded Bed Reactor
esp	Electrostatic Precipitator
f	Fan
ff	Fabric Filter
fl	Facultative Lagoon
fp	Facultative Pond
fpr	Filter Press
fr	Fixed Film Reactor
ft	Flat Bed Turbine Flocculator
hf	Horizontal Baffled Flocculator
hh	Hoods for Hot Processes

hr	Horizontal Baffled Rapid Mix Unit
i	Incineration
ie	Ion Exchange
if	Inline Blender Flocculator
ir	Inline Blender Rapid Mix Unit
ls	Lime Soda Softening
od	Oxidation Ditch
p	Proportionate Grit Chamber
pa	Grit Chamber with Parshall Flume
pf	Paddle Type Flocculator
poc	Post Chlorination
prc	Pre Chlorination
ps	Plate Settlers
rc	Rectangular Clarifier
rf	Rapid Gravity Filter
s	Skimming Tank
sa	Spray Aeration System
sdb	Sludge Drying Beds
sf	Slow Sand Filter
sp	Settling Chambers
t	Trickling Filter
th	Sludge Thickening
tr	Turbine Type Rapid Mix Unit
ts	Tube Settler
ur	Upflow Anaerobic Sludge Blanket
vr	Vertical Baffled Rapid Mix Unit
ws	Wet Scrubbers

Nomenclature

A	Area of a Unit
A_1	Area at First Stage
A_2	Area at Second Stage
A_a	Air Required/Flow
A_{ac}	Aerator Capacity
A_{af}	Area/Flow
A_{al}	Air Required per Unit Length
A_{ap}	Area Served by pipe
A_{ar}	Actual Air Required
A_{as}	Air Required/m^3 of Sludge
A_{bd}	Area of Blades
A_{bt}	Bottom Area
A_c	Clear Area
A_{cch}	Area of Combustion Chamber
A_{cs}	Cross-sectional Area
A_{db}	Area of Distribution Box
A_g	Grate Area
A_h	Area of Hot Source
A_{hl}	Area Through Which Heat Loss Occurs
A_{hh}	Area of Hood Face
A_{hy}	Area Based on Hydraulic Consideration
A_l	Area of Laterals
A_{le}	Area of Each Laterals
A_{lk}	Alkalinity
A_m	Area of Main Pipe
A_{mp}	Modified Area of Pond

A_n	Net Area of Rack Required
A_o	Area of Orfice
A_{op}	Area of Openings
A_{pf}	Area of Perforations
A_{pd}	Area of Paddles
A_{pl}	Area of Plates
A_{pr}	Aeration Power Requirement
A_{pt}	Area of Ports
A_{pw}	Plan Working Area
A_r	Volume of Air Required
A_{ras}	Area of Rising Air Stream
A_{rf}	Roof Area
A_{rs}	Area of Resin Bed
A_{si}	Area of i^{th} Section
A_{sw}	Side Wall Area
A_t	Area of Tube
A_{th}	Throat Area
Al	Alum Dose
Al_k	Alkalinity
a	Weir Dimension
B_c	Blower Capacity
bhp	Brake Horse Power
bsrt	Mean Cell Residence Time
B_p	Net Biomass Produced
B_s	BOD in Sludge
C	Clearance
C_a	Ammonia Concentration
C_D	Drag Coefficient
C_{ad}	Adsorption Capacity of Adsorbent
C_d	Capacity of a Single Diffuser
C_e	Effluent Coliform Concentration

C_h	Hydrogen Sulfide Concentration
C_{ii}	Iron Concentration
C_{mn}	Manganese Concentration
C_0	Influent Coliform Concentration
C_{op}	Optimum Chlorine Dose
C_p	Concentration of Pollutant Specie
C_r	Circumference at Corner
C_{sv}	Common Salt Value
C_v	Coefficient of Velocity
cd	Coefficient of Discharge
cl_a	Additional Chlorine Dose
cl_e	Chlorinator Capacity
cl_d	Dose of Disinfectant
cl_p	Chlorine Demand at Peak Flow
cl_r	Disinfectant Requirement
cl_t	Total Chlorine Dose
D	Depth
D_1	Depth at First Stage
D_2	Depth at Second Stage
D_a	Actual Depth
D_b	Depth of Baffle Wall
D_{bd}	Depth of Blending Tank
D_{ch}	Depth of Chamber
D_{co}	Depth of Compartment
D_{db}	Depth of Distribution Box
D_{dz}	Depth of Flow Distribution Zone
D_f	Depth of Flow
D_{fu}	Depth of Flow in the Upstream Leg of Flume
D_{fmn}	Depth of Flow at Minimum Flow Condition
D_{fmx}	Depth of Flow at Peak Flow Condition
D_g	Depth of Gravel Bed

D_{gg}	Gas Diffusivity
D_{ic}	Depth of Influent Channel
D_{ll}	Diffusivity of Liquid
D_n	Dispersion Number
D_{nh}	Depth of Notch
D_o	Depth of Submerged Opening
D_{rs}	Depth of Resin Bed
D_s	Dispersion Coefficient
D_{ss}	Sand Depth
D_{sw}	Side Water Depth
D_{sz}	Depth of Sludge Zone
D_{szm}	Minimum Depth of Settling Zone
D_t	Total Depth
D_{tc}	Depth at Centre
D_{tr}	Depth in Trough
D_{ts}	Side Water Depth
D_{tz}	Depth of Thickening Zone
D_w	Water Depth
D_{we}	Depth of Flow Over Effluent Weir
d	Diameter of a Unit
d_1	Diameter at First Stage
d_2	Diameter at Second Stage
d_{as}	Diameter of Rising Air Stream
d_b	Diameter of Baffle Wall
d_{cc}	Diameter of Central Column
d_{bd}	Diameter of Blending Tank
d_{cch}	Diameter of Combustion Chamber
d_{ch}	Diameter of Chamber
d_{ci}	Diameter of Cascade at i^{th} Step
d_{cs}	Cut Size Particle Diameter
d_{cy}	Diameter of Cyclone

d_{de}	Diameter of Dust Exit
d_{ecy}	Diameter of Exit Cylinder
d_{ep}	Diameter of Effluent Pipe
d_f	Diameter of Filter
d_h	Diameter of Hood
d_{hs}	Diameter of Hot Source
d_i	Diameter of Impeller
d_{ip}	Diameter of Influent Pipe
d_l	Diameter of Laterals
d_m	Diameter of manifold
d_{mp}	Diameter of Main Pipe
d_n	Diameter of Nozzle
d_o	Diameter of Orfice
d_p	Diameter of Particle
d_{pd}	Diameter of Farthest Paddle
d_{pf}	Diameter of Perforations
d_{pi}	Diameter of i^{th} Size Particle
d_{pt}	Diameter of Ports
d_{rc}	Revised Diameter of Tank
d_{rs}	Diameter of Resin Bed
d_s	Diameter of Slots
d_{so}	Diameter of Source
d_{ss}	Diameter of Each Section
d_t	Diameter of Tube
d_{th}	Throat Diameter
delta	Temperature Difference
E	Elevation Above MSL
E_a	Energy Stored in Algae
E_{cr}	Exchange Capacity of Resine
E_{lh}	Hood Entry Loss
E_{pc}	Enthalpy of Pollutant at Combustion Tempreture

E_{pi}	Enthalpy at Inlet Tempreture
E_r	Energy Required
E_s	Effective Size of Sand
F_{av}	Active Volume Fraction
F_b	Free board
F_{bp}	BOD Fraction in Primary Sludge
F_p	Packing Factor
F_{pg}	Fraction of Pollutants in Gas
F_r	Filtration Rate
F_v	VSS Fraction
F_w	Fraction of Water to Treated
G	Velocity Gradient
G_{ci}	Velocity Gradient in i^{th} Compartment
G_s	Specific Gravity of Sand
g	Acceleration Due to Gravity
g_s	Grit Storage Space
g_c	Grit Content
g_t	Total Amount of Grit
H	Height of A Unit
H_1	Hydraulic Loading at First Stage
H_2	Hydraulic Loading at Second Stage
H_{50}	Head Loss at 50% Clogging
H_a	Head at Average Flow
H_b	Height of Baffle
H_{bd}	Height of Blade
H_{bt}	Height of Booth
H_c	Heat of Combustion
H_{cb}	Height of Cabinet
H_{co}	Height of Each Compartment
H_{cy}	Height of Cyclone
H_d	Total Displaced Height

H_e	Height of Entrance
H_{fc}	Floating Cover
H_g	Grit Accumulation
H_{ge}	Heat Available from Flue Gas
H_{gs}	Height of Gas Exit
H_{hs}	Height of Heat Source Above Hood Face
H_{hp}	Height of Hood Face from Hypothetical Point Source
H_i	Head Loss in the Influent Structure
H_{iw}	Head Over Influent Weir
H_l	Head Loss
H_{lc}	Head Loss in the Channel
H_n	Head at Nozzle
H_{nh}	Head Loss Over Notches
H_o	Head Over Orfice
H_{pd}	Height of Paddle
H_{pl}	Height of Plate
H_{pt}	Height of Plates
H_r	Heat Required
H_{rl}	Radiation Loss
H_{rm}	Height of Room
H_s	Height of Each Step
H_{sb}	Height of Scum Blanket
H_t	Total Height
H_w	Head Over Weir
H_{wb}	Height of Weir Crest Above Bottom
h_a	Total Accumulated Hardness
h_c	Carbon Dioxide
h_{ca}	Calcium Hardness as $CaCO_3$
h_e	Effluent Hardness as $CaCO_3$
h_f	Friction Loss
h_i	Influent Hardness as $CaCO_3$

h_{mg}	Magnesium Hardness as $CaCO_3$
h_r	Hydraulic Mean Radius
hrt	Hydraulic Retention Time
hrt_{bd}	Hydraulic Retention Time in Blending Tank
hrt_{co}	Hydraulic Retention Time in Each Compartment
hrt_d	Hydraulic Retention Time in Distribution Box
hrt_p	Hydraulic Retention Time at Peak Flow
hrt_s	Actual Solid Retention Time
i	Number
K	Reaction Rate Constant
K_t	Reaction Rate Constant at any Temperature
K_{20}	BOD Removal Rate Constant at 20^0C
K_e	Coefficient of Expansion
k_d	Constant
k_t	Reaction Rate Constant at any Temperature, t
L	Length of a Unit
L_a	Arm Length
L_{aa}	Approximate Aperture Length
L_{as}	Length of Each Arm Section
L_b	Length of Baffles
L_{bd}	Length of Blade
L_{br}	Length of Brine Tank
L_c	Length of Channel
L_{cb}	Length of Cabinet
L_{cc}	Crest Length at Weir Crest
L_{cch}	Length of Combustion Chamber
L_{ch}	Length of Chamber
L_{cn}	Length of Cone
L_{cy}	Length of Cylinder
L_{db}	Length of Distribution Box
L_{ds}	Lime Dose/Sludge Solids

L_e	Effective Length
L_{ee}	Equivalent Length
L_{ew}	Length of Effluent Weir
L_h	Length of Hood
L_{he}	Hood Entry Length
L_{hm}	Minimum Hydraulic Loading Rate
L_{hs}	Length of Hot Source
L_{ic}	Length of Influent Channel
L_{iw}	Length of Influent Weir
L_l	Length of Laterals
L_{lp}	Total Length of the Pass Around the Baffle
L_m	Mid Length
L_o	Length of Outlet Zone
L_{pl}	Length of Plate
L_{pse}	Length of Passage in Each Section
L_r	Length of Rotor
L_{ras}	Length of Rising Air Jet at Hood Face
L_{rc}	Length of Rotor on the Basis of Circulation
L_{re}	Length of Rotor in Each Ditch
L_{rt}	Relative Length of Tube
L_{ro}	Length of Rotor Based on Oxygenation Capacity
L_{rs}	Length of Rising Air Jet
L_s	Length of Slots
L_{sh}	Length of Shaft
L_{sr}	Actual Solid Loading Rate at Average Flow
L_{sta}	Length of Stator
L_t	Total Length
L_{tm}	Length of Tube Module
L_{tr}	Transition Relative Length
L_{tu}	Slant Length of Tube
L_w	Length of Weir Provided

L_{wp}	Length of Weir Plate
L_{wt}	Length of Weir at the Top of Chamber
LL	Latitude
l_d	Lime Dose
l_{di}	Inlet Dust Loading
l_{do}	Outlet Dust Loading
l_{ds}	Lime Dose/Sludge Solids
l_{ex}	Excess Lime
l_h	Hydraulic Loading Rate
l_{hm}	Minimum Hydraulic Loading Rate
l_r	Lime Required
l_s	Solid Loading Rate
l_{sd}	Daily Soda Requirement
l_v	VSS Load
l_{vr}	VSS Loading Rate
l_{ws}	Loss of Water in Desludging
M_g	Molecular Weight of Gas
M_{gc}	Mass Flow Rate of Contaminated Gas
M_p	Molecular Weight of Pollutant
M_{pp}	Mass of Pollutant to be Adsorbed
M_s	Mass of Sludge Produced
M_{sf}	Mass of Sludge Leaving the Digester
M_{si}	Total Mass of Sludge Reaching the Digester
M_{sp}	Mass of Sludge Produced
M_{sr}	Mass of Solids Reduced
M_{st}	Amount of Solids in Sludge Thickening Zone
M_{sw}	Quantity of Sludge Withdrawn
M_{ts}	Total Solids
N	Number of Units
N_a	Number of Arms
N_b	Number of Baffle Walls

N_{bd}	Number of Blades
N_{bl}	Number of Blending Tanks
N_{bus}	Number of Bus Sections
N_c	Number of Clear Spacings
N_{ch}	Number of Channels
N_{cl}	Number of Chlorinators
N_{co}	Number of Compartments
N_d	Number of Data set
N_{dr}	Number of Diffuser Rows
N_{dtr}	Number of Diffuser Tubes per Row
N_e	Excess Nitrogen Required
N_{fc}	Number of Feeder Channels
N_{gs}	Number of GLSS Separators
N_i	Influent Nitrogen Concentration
N_l	Number of Laterals
N_{ll}	Number of Lateral Effluent Launders
N_{ln}	Number of Nozzles Along Length
N_{lp}	Number of Lagoons in Parallel
N_{ls}	Number of Lagoons in Series
N_n	Number of Nozzles
N_{nh}	Number of Notches
N_{nl}	Number of Nozzles per Unit Length
N_{np}	Number of Nozzles per Pipe
N_{nw}	Number of Nozzles along Width
N_o	Number of Orfices
N_{op}	Number of Openings
N_{os}	Number of Orfices in Each Section
N_p	Number of Pipes
N_{pd}	Number of Paddles
N_{pds}	Number of Paddles per Shaft
N_{pf}	Number of Perforations

N_{pfc}	Number of Primary Feeders per Channel
N_{pfe}	Number of Primary Feeders
N_{pfl}	Number of Primary Feeders per Lateral
N_{pl}	Number of Plates
N_{pp}	Number of Ponds in Parallel
N_{ps}	Number of Ponds in Series
N_{pt}	Number of Ports
N_r	Number of Rotors
N_s	Number of Slots
N_{st}	Number of Steps
N_{sc}	Number of Sections
N_{sh}	Number of Shafts
N_t	Number of Diffuser Tubes
N_{tc}	Number of Tubes in a Column
N_{tr}	Number of Washwater Troughs
N_{tu}	Number of Turns in Cyclone Chamber
N_u	Number of Transfer Units in Absorption Tower
n	Manning's Coefficient
O_1	Organic Loading Rate at First Stage
O_2	Organic Loading Rate at Second Stage
O_b	Oxygen Required per kg of BOD Removed
O_l	Organic Loading Rate Based on Latitude and Elevation
O_r	Oxygen Required
O_{rc}	Oxygenation Capacity
O_{rd}	Design Oxygen Required
O_s	Oxygen Required per kg of Solid Reduced
O_t	Organic Loading Rate Based on Temperature Condition
O_{tc}	Oxygen Transfer Capacity
O_{ts}	Oxygen Capacity at Standard Conditions
P	Population
P_{av}	Percentage Average Solid Concentration

P_{br}	Percentage Solution of Brine
P_c	Initial Phosphorous Content
P_{ds}	Polymer Dose/Sludge Solids
P_{dt}	Tower Pressure Drop
P_e	Excess Phosphorous Required
P_{es}	Desired Percentage Solid Concentration
P_f	Performance Factor
P_i	Power Input
P_{is}	Percentage Original Solid Concentration
P_l	Power Required per Unit Length of Rotor
P_m	Motor Power
P_o	Outlet Pressure
P_{oc}	Outlet Pressure at Compressor
P_{pf}	Power per Unit Flow of Water
P_{ps}	Static Pressure
P_r	Power Required
P_{rc}	Power Required in Each Compartment
P_{rm}	Power Required for Mixing Consideration
P_s	Percentage Solids in Sludge
P_{sf}	Fan Static Pressure
P_v	Power Required per Unit Volume
P_{vm}	Minimum Power Required
P_{vp}	Velocity Pressure
P_{wd}	Percentage Water Lost in Desludging
p	Atmospheric Pressure
p_s	Storage Pressure
pf	Peaking Factor
Q_a	Average Flow to a Unit
Q_{aa}	Discharge per Unit Arm
Q_{aal}	Permissible Average Flow Per Unit Aperture Length
Q_{ac}	Discharge in Each Channel

Q_{acm}	Exhaust Rate w.r.t Air Change per Minute
Q_{ae}	Average Flow in Each Unit
Q_{ag}	Actual Volumetric Flow Rate of Gas
Q_{ap}	Discharge per Unit Area in Each Primary Feeder
Q_{ai}	Discharge per Arm
Q_{as}	Discharge in Each Secondary Feeder
Q_b	Quantity of Backwash Water
Q_{be}	Exhaust Rate per Unit Belt Width
Q_{cse}	Exhaust Rate per Unit Cross-sectional Area
Q_d	Design Flow
Q_{dl}	Dilution Water
Q_e	Design Exhaust Rate
Q_f	Discharge Through First Hole
Q_{fg}	Flow Rate of Fuel Gas
Q_{fgc}	Flow Rate of Fuel Gas at Combustion Chamber
Q_g	Gas Flow Rate
Q_{gc}	Flow Rate of Contaminated Gas
Q_{ge}	Exhaust Rate per Unit Grate Area
Q_{go}	Outlet Gas Flow Rate
Q_i	Flow in i^{th} Interval
Q_l	Flow Through Laterals
Q_{lo}	Outlet Liquid Flow Rate
Q_{me}	Minimum Flow in Each Unit
Q_{mp}	Mass Flow Rate of Pollutant
Q_n	Flow Through Nozzle
Q_o	Discharge Through Orfice
Q_{op}	Exhaust Rate per Unit Open Face
Q_p	Peak Flow to a Unit
Q_{pa}	Actual Pollutant Flow Rate
Q_{pe}	Peak Flow in Each Unit
Q_{per}	Design Flow per Unit

Q_{pl}	Exhaust Rate with respect to Plan Working Area
Q_{ple}	Exhaust Rate per Unit Plan Working Area
Q_q	Discharge in Each Quarter Region
Q_{rf}	Regeneration Flow Loading
Q_s	Sludge Flow Rate
Q_{sp}	Sludge per Capita per Year
Q_{st}	Total Sludge Flow
Q_t	Total Flow
Q_{tg}	Total Flow Rate of Gases
Q_{to}	Average Flow in Thickener
Q_{ww}	Quantity of Backwash Water
R_{st}	Return Sludge
R_1	Recirculation Ratio at First Stage
R_2	Recirculation Ratio at Second Stage
R_{ab}	Ratio of Air to BOD Removal
R_{ac}	Rate of Air Change per Minute
R_{acl}	Average Chlorine Demand
R_{ad}	Adsorbent Required
R_{av}	Ratio of Air to Volume of Container
R_{aw}	Ratio of Air to Water
R_{bc}	Ratio of Diameter of Baffle Wall to Clarifier
R_{bt}	Ratio of Diameter of Baffle Wall to Diameter of Thickener
R_{bv}	Bod_5/VSS
R_{bw}	Ratio of Length of Blade to Width of Tank
R_{cv}	Corrected Visible Radiation
R_d	Daily Radiation
R_{dd}	Ratio of Diameter to Depth of Tank
R_{ddi}	Ratio of Diameter of Impeller to Diameter of Tank
R_e	Reynolds Number
R_{et}	Ratio of Width of Effluent Launder to Diameter of Tank
R_f	Rate of Filtration

R_{fm}	Food to Microorganism Ratio
R_{hd}	Ratio of Height to Diameter of Tank
R_{hw}	Ratio of height to Width
R_{ld}	Ratio of Length to Depth
R_{ldb}	Ratio of Length of Blade to Diameter of Tank
R_{lh}	Ratio of Length to Height
R_{lhb}	Ratio of Length to Height of Blade
R_{lds}	Ratio of Length of Stator to Diameter of Tank
R_{lp}	Ratio of Area of Laterals to Area of Perforations
R_{lw}	Ratio of Length to Width
R_{lwb}	Ratio of Length to Width of Blade
R_{lwbt}	Ratio of Length to Width of Brine Tank
R_{lwdb}	Ratio of Length to Width in Distribution box
R_{lwp}	Ratio of Length to Height of Plate
R_{lwr}	Ratio of Length to Width of Rinse Tank
R_{lws}	Ratio of Length to Width of Slots
R_{ml}	Ratio of Area of Main Pipe to Area of Laterals
R_{mn}	Minimum Radiation
R_{mx}	Maximum Radiation
R_{oa}	Ratio of Oxygen to Algae
R_{ol}	Ratio of Spacing of Orifices to Spacing of Laterals
R_{pl}	Area of Perforations per Unit Length of Laterals
R_{pcl}	Maximum Chlorine Demand
R_{pf}	Ratio of Area of Perforation to Area of Filter
R_{pp}	Precipitation Rate
R_{py}	Polymer Required
R_s	Radius of Spray
R_{sop}	Ratio of Spacing of Orfice to Laterals
R_w	Weir Loading Rate
R_{wd}	Ratio of Width to Depth
R_{wdbr}	Ratio of Width to Depth of Brine Tank

R_{wdr}	Ratio of Width to Depth of Rinse Tank
R_{wh}	Ratio of Width to Height
R_{whbr}	Ratio of Width to Height of Brine Tank
R_{whr}	Ratio of Width to Height of Rinse Water Tank
R_{ww}	Wash Water Rate
S	Screen or Sludge Content
S_{bb}	Size of Bubble Cap
S_c	Side of Each Compartment
S_{cf}	Sky Clearnace Factor
S_{co}	Side of Compartment
S_d	Soda Dose
S_{de}	Excess Soda Dose
S_e	Effluent BOD Concentration
S_{e1}	Effluent BOD from First Stage
S_{ef}	Final Effluent BOD
S_{er}	Effluent BOD After Recirculation
S_f	Shape Factor
S_g	Size of Gravel
S_l	Solids Loading Rate
S_o	Influent BOD Concentration
S_{op}	Side of Openings
S_{or}	Side of Orfice
S_p	Normal Packing Size of Absorption Tower Packing Material
S_r	Solid Loading Rate
S_s	Side of Slots
S_{sd}	Solids in Digested Sludge
S_{si}	Solids in Influent Sludge
S_t	Side of Tubes
S_w	Submergence of Baffle Wall
sor	Surface Overflow Rate
sor_p	Surface Overflow Rate at Peak Flow

svi	Sludge Volume Index
svr	Sludge Volume Ratio
T_a	Ambient Temperature
T_c	Contact Time
T_{ct}	Combustion Temperature
T_d	Operating Days
T_{dg}	Digestion Temperature
T_e	Exposure Time
T_g	Gas Temperature
T_h	Operating Hours
T_{hs}	Temperature of Hot Source
T_{it}	Inlet Temperature
T_{lb}	Time Lost During Backwash
T_p	Pond Temperature
T_{pl}	Thickness of Plate
T_r	Time Interval of Successive Regeneration
T_{rt}	Regeneration Time
T_s	Storage Temperature
T_{st}	Thickened Sludge Temperature
T_t	Thickness of Tube
T_w	Influent Water Temperature
t_c	Cleaning Frequency
t_d	Digestion Period
t_e	Time of Exposure
t_g	Gas Storage Period
t_i	Time Interval of Flow Data
tss_b	TSS Concentration in Blended Sludge
tss_e	Effluent Total Suspended Solid Concentration
tss_i	Influent Total Suspended Solid Concentration
tss_o	TSS Content of Thickener Overflow
U_{gt}	Gas Transfer Unit

U_{lt}	Liquid Transfer Unit
U_{og}	Overall Gas Transfer Unit
U_s	Uniformity Coefficient of Sand
V	Volume of a Unit
V_1	Volume at First Stage
V_2	Volume at Second Stage
V_a	Volume of Air Required under Standard Condition
V_{ad}	Active Digester Volume
V_{af}	Digester Volume at Average Flow Conditions
V_{am}	Volume of Air Required Based on Mixing Condition
V_{av}	Volume at Average Flow
V_{bd}	Volume of Blending Tank
V_{br}	Volume of Brine Water
V_{brw}	Volume of Brine Water Tank
V_{cd}	Volume Based on Per Capita Basis
V_{co}	Volume of Each Compartment
V_d	Design Volume
V_{db}	Volume of Distribution Box
V_{dr}	Volume of Digester Required
V_e	Volume of Each Equalization Chamber
V_f	Flow Velocity Through Racks
V_g	Volume of Gas Produced
V_{hrt}	Volume Based on Hydraulic Retention Time
V_l	Volumetric Loading
V_m	Volume of Methane Produced
V_o	Volume of Air Required at Standard Conditions
V_{om}	Volume of air Required Based on Mixing Conditions
V_p	Volume at Peak Flow
V_{rs}	Volume of Resin Bed
V_{rw}	Volume of Rinse Water
V_s	Volume of Sludge

V_{sc}	Scour Velocity
V_{sg}	Storage Volume
V_{st}	Volume of Straight Portion of Oxidation Ditch
V_t	Volume Treated per Unit Length of Rotor
V_{tg}	Volume of Total Gas Produced
V_{ts}	Volume of Thickened Sludge
V_{vs}	Volume of Digester
v_a	Velocity Through Arms
v_{af}	Actual Velocity of Flow
v_{bg}	Bulk Gas Velocity
v_{bs}	Belt Speed
v_{cc}	Velocity Through Central Column
v_{dc}	Cross-draft Velocity
v_{cch}	Velocity Through Combustion Velocity
v_{ch}	Velocity Through Each Channel
v_{dd}	Downdraft Velocity
v_{ep}	Permissible Velocity Through Effluent Pipe
v_f	Velocity of Flow
v_{fc}	Velocity Through Feeder Channel
v_{gi}	Inlet Gas Velocity
v_{hh}	Velocity Head
v_t	Tip Velocity of Paddle
v_{id}	In-draft Velocity
v_n	Velocity Through Nozzle
v_o	Outlet Velocity
v_{op}	Velocity Through Openings
v_{pc}	Permissible Velocity Through Each Connecting Pipe
v_{pd}	Velocity Through Paddles
v_{pp}	Permissible Velocity Through Primary Feeder
v_{ps}	Permissible Velocity Through Slots
v_{pt}	Velocity Through Ports

v_r	Rise Velocity
v_{ra}	Velocity Through Remaining Area
v_{rh}	Velocity of Rising Air Jet
v_{rw}	Rinse Water Loading
v_s	Velocity Through Slots
v_{sc}	Scour Velocity
v_{sh}	Speed of Paddle Shaft
v_{slg}	Superficial Linear Gas Velocity
v_{smg}	Superficial Mass Gas Velocity
v_{sr}	Service Flow Rate
v_{st}	Settling Velocity
v_{sup}	Superficial Velocity
v_{th}	Throat Velocity
v_w	Wind Velocity
W	Width of a Unit
W_1	Organic Loading at First Stage
W_2	Organic Loading at Second Stage
W_a	Weight of Algae Required
W_{aa}	Width of Aperture
W_b	Width of Bars
W_{bd}	Width of Blade
W_{be}	Bottom Width of Effluent Channel
W_{bi}	Bottom Width of Influent Channel
W_{bs}	Width of Belt
W_{bt}	Bottom Width of Oxidation Ditch
W_c	Clear Width
W_{cb}	Width of Cabinet
W_{ch}	Width of Chamber
W_{co}	Width of Compartment
W_{db}	Width of Distribution Box
W_e	Effective Width

W_{el}	Width of Effluent Launder
W_{gi}	Width of Gas Inlet
W_h	Width of Hood
W_{hs}	Width of Hot Source
W_{ic}	Width of Influent Channel
W_{ll}	Width of Launder
W_o	Width of Submerged Opening
W_p	Organic Load on Pond
W_{pd}	Width of Paddle
W_{pl}	Width of Plate
Wr	Width of Room
W_{ras}	Width of Rising Air Jet at Hood Face
W_{rs}	Width of Rising Stream
W_s	Width of Slot
W_{st}	Weight of Salt Required for Regeneration
W_t	Total Width
W_{th}	Width of Throat
W_{tm}	Width of Tube Module
W_{tp}	Top Width of Oxidation Ditch
W_{tr}	Width of Trough
w_g	Weight of Gas
w_{ge}	Weight of Gas Compressed
w_{pc}	Weight of Gas Produced
w_s	Weight of Salt Required
X	Mixed Liquor Volatile Suspended Solid(MLVSS)
X_l	VSS in Lagoon
X_p	MLVSS Produced
X_r	MLVSS of Required Sludge
X_s	Mixed Liquor Suspended Solid(MLSS)
X_{sp}	MLSS Produced
x_b	In front Distance of Baffle Wall

x_c	Distance from Center
x_{hp}	Height of Hypothetical Point Source to Hood Face
x_l	Distance Between Laterals
x_{sp}	Height of Hypothetical Point Source to Hot Source
x_{wb}	Distance of Work Place from Face of Booth
Y_1	Depth of Water at the Upper End Of Trough
Y_2	Critical Depth at the End of Effluent Launder
y	Spacing
y_{an}	Actual Nozzle Spacing
y_{ap}	Actual Spacing of Pipes
y_b	Spacing of Bars
y_c	Spacing of Bubble Caps
y_{gs}	Spacing of GLSS Separators
y_h	Spacing of Holes
y_l	Spacing of Laterals
y_{mp}	Minimum Spacing Between Pipes
y_n	Spacing of Nozzles
y_{nh}	Spacing of Notches
y_{nl}	Spacing of Nozzles Along Length
y_{nw}	Spacing of Nozzles Along Width
y_o	Spacing of Orfices
y_{ob}	Observed Yield Coefficient
y_{op}	Spacing of Openings
y_p	Spacing of Pipes
y_{pc}	Spacing of Primary Feeder Channels
y_{pd}	Spacing of Paddles
y_{pf}	Spacing of Perforations
y_{pl}	Spacing Between Plates
y_{pt}	Spacing of Ports
y_s	Spacing of Slots
y_{st}	Spacing of Trays

y_t	Theoretical Yield Coefficient
y_{tt}	Spacing of Troughs
y_w	Spacing of Weirs
Z	Elevation of Channel Bottom
Z_c	Clear Liquid Zone
α	Slope of Bars
θ	Slope
η	Efficiency
η_1	Efficiency at First Stage
η_2	Efficiency at Second Stage
η_{at}	Air Transfer Efficiency
η_d	Destruction Efficiency
η_{et}	Efficiency of Energy Transfer
η_i	Collection Efficiency of i^{th} Range Particle
η_m	Efficiency of Motor & Drive
η_{ot}	Oxygen Transfer Efficiency
η_s	Solid Reduction Efficiency
η_t	Overall Efficiency
η_{tss}	TSS Removal Efficiency
η_{tvs}	TVS Destruction Efficiency
η_u	Efficiency of Waste
μ	Specific Growth Rate
μ_g	Dynamic Viscosity of Gas
μ_l	Dynamic Viscosity of Liquid
μ_s	Viscosity of Sludge
υ_g	Kinematic Viscosity of Gas
υ_l	Kinematic Viscosity of Liquid
ω	Rotational Speed of Shaft
ρ_a	Density of Air

ρ_{bd}	Bulk Density of Adsorbent
ρ_g	Density of Gas
ρ_l	Density of Liquid
ρ_p	Density of Pollutant Specie
ρ_s	Particle Density

Abstract

In the present work an attempt has been made to develop a comprehensive software package for many of the activities related to environmental engineering profession. The package is aimed at assisting practicing engineers and education and training in water supply and pollution control operation. The package has been written in Turbo C language and can be used on any IBM PC AT or higher machines in MS DOS environment. The graphical details have been drawn in Auto CAD version 12.0 and its *.dxf format file has been called wherever required in the program

The package has been divided into four modules namely air pollution control, water supply, wastewater management and solid waste management. These modules further consist of different options. In this package air pollution control, water treatment system and wastewater treatment systems have been attempted. Air pollution control consists of design of local exhaust ventilation system (hood, duct and fan) and particulate and gaseous emission control devices (settling chamber, cyclones, electrostatic precipitator, absorption, adsorption and incineration, etc.). Water treatment system includes design of aeration, settling, rapid mix units, flocculation, filtration, softening, and disinfection processes. The wastewater treatment system has been classified into five categories – pretreatment consisting of screening, grit chamber, equalization and skimming whereas primary treatment consists of equalization, sedimentation, chemical treatment and aeration. The secondary process consists of activated sludge process, trickling filter, aerobic and facultative pond, aerated and facultative lagoon, oxidation ditch, and upflow anaerobic sludge blanket reactors. The sludge treatment includes the processes like thickening, aerobic and anaerobic digestion, sludge drying beds and filter press.

To provide the user useful insight into the options and help in decision making, ADVICE is incorporated, which is sub divided into three parts – DESCRIBE: a brief description of (un)favorable conditions for operation, PERFORMANCE: performance from the point of view of important and pertinent design parameters and

COMPARISON: a critical comparison of options from the point of view of operating features.

KEY WORDS

Software, Interactive Packages, Water Treatment System, Wastewater Treatment System, Air Pollution Control, Local Exhaust Ventilation, Gaseous Emission Control, Particulate Emission Control, Preliminary Treatment, Primary Treatment, Secondary Treatment, Tertiary Treatment, Sludge Treatment.

1 Prologue

The computer application in solving engineering problems, though started recently, has become an integral part of almost every field of engineering. With deepening of knowledge, more and more complexities and their consequences are cropping up, which require newer, faster and more sophisticated methods of data acquisition, storage, processing and analysis. The development of supporting software for man-machine dialogue has introduced a variety of software packages in every specialization of engineering.

The environmental field too, is experiencing an era of information explosion and technological revolution due to increased concern for environment. Growth of tremendous information in several fields, heavy regulation books and guidelines have necessitated the computer application in environmental engineering. The developed countries are producing environmental software at a tremendous pace, which deal with diverse fields, from air dispersion modeling to treatment plant design, hazardous assessment of chemical releases to huge databases. These software have a sound technical content and are produced commercially.

Contrary to developed countries, Indian environmental software scenario is rather dull. The computer application in the specialization is still in its infancy stage. The software available are numbered, and are mostly the products of technical institutions and research organizations. Due to different climatic and operating conditions the databases used in internationally available software are not best suited for countries like India. Therefore, there is a need to develop software to suit local conditions and regulations.

Indian journey to make design software may said to be started in late eighties. Islam (1987) developed the IBM based design and information aid for water treatment plants. Subsequently, Ummat (1988), initiated the development of INDETREP-"An Interactive Package For The Design Of Effluent Treatment Plants". This software was developed on ND-560-Cx super mini computers operating on SINTRAN-III. 'INDETREP' was the first structured menu driven software developed in India. But it lacked the system importability, flexibility in unit selection, guidelines, etc, which otherwise would have made the software very useful. Further improvements were done by Funkwal (1989) and Mishra *et al.* (1989) in developing INDETREP II and PCINDETREP. These software were written in Turbo Pascal version 4.0 supported on any IBM based PC XT/AT, and included various options to make the software informative and useful to a large extent. Various options of secondary treatment units and guidelines were added to provide the user insight about the unit processes, treatment efficiency and performance evaluation. In 1990 Apurb Anand and Dixit developed the modified version PCINDETREP – II. However, in this, anaerobic treatment units and sludge treatment options were excluded. For water treatment, WTRP (Sharma *et al.*, 1989) and WATREP (Dixit, 1992) were developed at IIT Kanpur. WATREP may be considered as one of the few water treatment software that gives enough insight about the water treatment process as a whole.

In air pollution control too, several small efforts have been started to deal with the various aspects of emission control technologies. For example, some efforts were made to develop software for design of (i) local exhaust ventilation system (Anand, 1996) (ii) control of gaseous pollutants (Goel, 1996) and (iii) control of particulates (Sinha, 1995). These software were first of their kind in India.

The above mentioned small efforts have been instrumental to raise the scope, expectations and utility of software packages in environmental engineering applications. However, almost all software related research work felt the need for development of a comprehensive software package for environmental engineers. Further, the research works done earlier are system dependent, some of them being operative on main frame computers. Thus it was not possible to combine them together. The need of better visuals, and flexibility in unit selection too, made it

almost necessary to work for such software. Besides this, it was felt that provision for range values of process variables will help the user to a large extent in fully utilizing the potential of a unit operation and make him understand the limitations and/or applicability of the process. It is to satisfy some of these ends that the present work was initiated.

2 Literature Review

With the advent of computers in the later half of the 20^{th} century, the educational and social scenario have completely changed. Today the market is floating with software, which serve as an essential tool in achieving several tasks such as solving the complex mathematical problems, predicting the future impact, providing a reasonably large database for numerous applications, etc.

Computer application in environmental engineering has started very late. Earlier, when the government agencies were not strict to enforce the legislation, environmental consequences invariably occupied the back seat during industrialization process. The rapid, thoughtless development, further aggravated the problem, forging everyone to concern not for the present pollution level, but the future contamination too. As government agencies today require more and more information, engineers and managers are trying to seek out means to handle efficiently and effectively the volume of necessary data. In this context, environmental software play a vital role, meeting the huge requirement of design software, databases for hazardous chemicals, air modeling and monitoring, etc.

Environmental software save time in solving complex problems. It helps in predicting the future impact of certain hazardous emissions through modeling and warn us of the consequences. It reduces the complexity of hand computations and the cost of evaluation and decision for a suitable waste management technique is also low. These software can readily do comparative evaluation of various treatment schemes and last but not the least, it can be operated by a less competent person too with a little training. Today software are available for hazardous assessment of chemical releases, track and monitor anything that could be possibly tracked or monitored, analyze samples, manage health and safety, model groundwater flow and

lot more (Cheremisinoff, 1987; Rich, 1988; 1990; 1991; 1992; 1994; Gupta *et al.*, 1992; Hodson and Kilbourne, 1996).

Barring few exceptional cases, commercially the software production in environmental engineering field started in 1980's. In 1985, pollution engineering reported the availability of about fifty software in international market (Rich, 1992). These software were dealing with diverse fields ranging from air dispersion modeling to design of pretreatment units, hazardous waste management to databases, providing the complete environmental regulations. There were several programs available on storm water management, basin data management, meteorological monitoring, etc. These software were fresh attempts in this field and initially lacked reliability, system compatibility, module flexibility and the technical content. But the software market exploded soon, rising exponentially every year. In 1990, 357 software were available (Rich, 1990). This number has grown to about 600 in 1996 (Hodson and Kilbourne, 1996). These software are competing each other in every respect, from technical support to user interaction, system compatibility to operational reliability. Today they are dealing with diverse fields like air dispersion modeling, design of treatment units, energy analysis, chemical analysis, distribution system, hazardous waste management and tracking, groundwater movement and modeling etc. in environmental engineering. The government agencies and technical institutions have found a useful tool to enforce and regulate the environmental regulations, publicize and attract the common public, besides using it as an effective design tool for various options. These programs are designed to help environmental professionals do their job better and to remain competitive as the environmental market continues to expand globally.

The software development in India is still in its rudimentary stage. The reason may be cited as – India is still a developing country and environmental problem is considered secondary in comparison to overall material growth. The issue of food and employment outweighs the environmental complications originating from discharge of untreated wastewater into river streams, uncontrolled air emissions and unsafe hazardous waste disposal. The environmental regulations are not enforced strictly and discharge limits are less stringent in comparison to developed world. There is a lack of awareness among people with respect to environmental problems. But in spite of that, several attempts have been made so far to develop software to meet the local

requirements. Contrary to commercialized software production in developed countries, Indian software are developed by educational institutions and research organizations. There have been several scattered efforts to develop in-house software in India. Environmental engineering groups at the Indian Institute of Technology, Kanpur and Bombay have put their efforts in an organized way to develop software to cater the local requirements. Software dealing with air dispersion modeling (Prasad, 1989), water quality modeling (Modak *et al.*, 1988; Gelda, 1989), water and wastewater treatment plant design (Ummat, 1988; Funkwal, 1989; Mishra *et al.*, 1989; Anand and Dixit, 1990), ocean outfall design (Matu and Kumar, 1988), risk assessment and environmental impact of industries (Dhoondia, 1987), optimized phased development of treatment plants (Naik, 1988), etc, have already been developed. These software have been put to limited use by pollution control agencies and educational institutions.

These software are simple in operation, have a sound technical content and can be put readily as training and educational tool in various organization. During operation, they provide useful information about the various options, which help in comparing the utility of a particular process. With an improved user interaction and graphics, it can compete with the outside world.

There are some inherent problems with Indian environment software industry. Since Indian software are mostly the product of educational and research institutions, they do not try to meet the expectations of outside world. The software updating is a big problem due to lack of interest. The field of interest is also less diverse as compared to the developed country's interest, and mainly it serves the academic purposes. The software supportability and flexibility is poor. Several areas of prime interest are still untouched.

3 Objectives and Scope

The review of literature presented in previous chapter reveals that the development of a comprehensive software package dealing with many aspects of environmental engineering suited to Indian conditions has not yet been attempted. As such, the principle objective of the present work is to develop a comprehensive software package for environmental engineering professionals that will serve the dual purpose of (i) assisting the practicing engineers in analysis and design, and (ii) education and training. The overall objectives of the present work can be briefed as follows.

- Compilation of information for various physical, chemical, physicochemical and biological processes for water and wastewater treatment, and air pollution control equipment.
- Development of a knowledge base to assist user in selection process.
- Providing a flexible selection system through which user can navigate with ease.

The present study is limited to the following aspects of the package.

- Development of an overall master menu selection system for the selection of units.
- Inclusion of design algorithms of almost all treatment units with specified range in which it works well.
- Design of treatment units to include water and wastewater treatment, local exhaust ventilation and emission control devices.
- Preparation of flow sheets and conceptual diagrams for the option implemented.
- Development of a guidance system in the package to advise the user on selection at various levels.

4 Software Structure and Features

4.1 Program Structure

The overall structure of the package is schematically represented in Figure 4.1. Advice is available at all levels wherever selection of an option from a set of options is required. The package consists of different modules/unit operations dealing with various environmental engineering problems. Unit identification causes the design of unit, generation of graphical and digital output and formation of the process chain by queuing the design units, wherever applicable. The post design features are available at the end of design of each unit, which when invoked displays flow sheet, and digital and graphical outputs.

4.2 General Program Logic

The present package has been developed keeping in view the general nature of the package and expected use by the end user. The ultimate objective is to provide the user a workable design of treatment units and also give sufficient flexibility to select a unit depending upon one's judgement.

Every unit in the package has been assigned an identification number, which is stored in a file, when the unit is selected as a part of treatment process. The list of identification number is given in Tables 4.1, 4.2, and 4.3 for air pollution control, water treatment system and wastewater treatment system respectively.

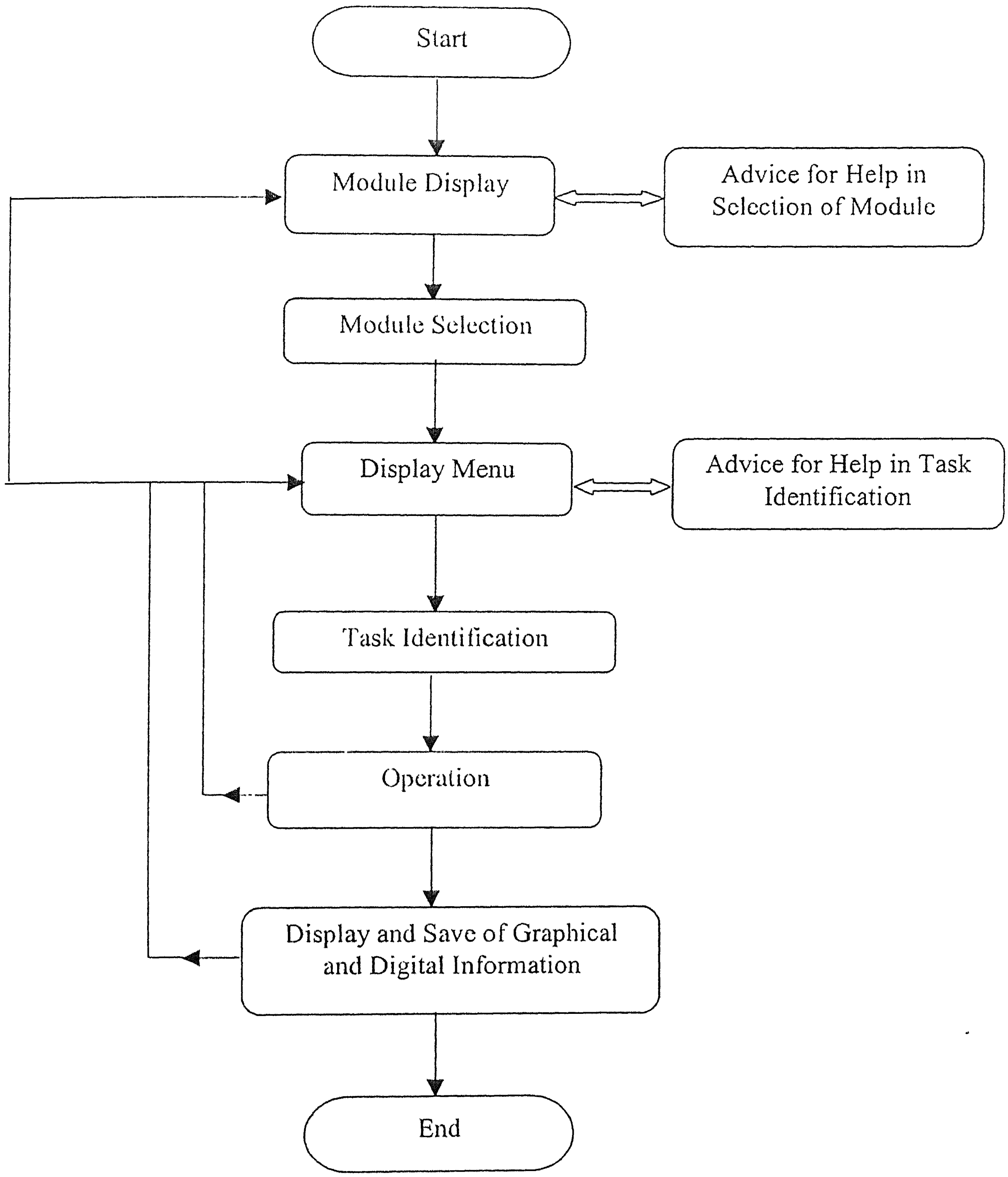

Figure 4.1: Overall Structure of the Package

Table 4.1: Identification Number Associated with Air Pollution Control

UNIT	TYPE	IDENTIFICATION NUMBER
Local Exhaust Ventilation	Hood	11100
	Duct	11200
	Fan	11300
Emission Control		
Particulate Control	Settling Chambers	12110
	Cyclone Chambers	12120
	Dry Scrubbers	12131
	Wet Scrubbers	12132
	Fabric Filter	12140
	Electrostatic Precipitator	12150
Gaseous Control	Packed Bed Absorption	12211
	Bubble Tray Absorption	12212
	Fixed Bed Adsorption	12220
	Condensation	12230
	Incineration	12240

The graphic visuals and interactions are accomplished by Turbo C – VER 3.0(1992). The current version of the package can be run on IBM PC XT/AT or compatible with or without color monitors.

The graphical database has been generated in Auto CAD version 12.0 to show the orthographic details of the unit processes. The *.dxf file generated through this package has been used as input file in a computer program written in 'C' language, which reads the coordinates of the figure and subsequently draws on the screen using the graphical capabilities of the Turbo C package.

Table 4.2: Identification Number Associated with Water Treatment System

UNIT	TYPE	IDENTIFICATION NUMBER
Aeration	Diffused	21100
	Spray	21200
	Cascade	21300
Settling	High Rate Tube Settler	22110
	High Rate Plate Settler	22120
	Rectangular	22210
	Radial Flow Circular	22221
	Circum. Flow Circular	22222
Rapid Mix	Jet Injector	23110
	Inline Blender	23120
	Turbine Type	23130
	Horizontal Baffled	23210
	Vertical Baffled	23220
Flocculation	Inline Blender	24110
	Paddle Type	24120
	Flat Blade Turbine	24130
	Vertical Baffled	24210
	Horizontal Baffled	24220
Softening	Lime Soda Softening	25100
	Ion Exchange	25200
Filtration	Slow Sand Filtration	26100
	Rapid Gravity Filtration	26200
Disinfection	Chlorination	27110

Table 4.3: Identification Number Associated with Wastewater Treatment

UNIT	TYPE	IDENTIFICATION NUMBER
Preliminary Treatment	Bar Racks	31100
	Skimming	31200
	Prop. Grit Chamber	31310
	Parshall Grit Chamber	31320
	Aerated Grit Chamber	31330
	On-line Equalization	31410
	Off-line Equalization	31420
Primary Treatment	Rectangular	32110
	Radial Flow Circular	32211
	Circum. Flow Circular	32212
Secondary Treatment	Activated Sludge Process	33110
	Trickling Filter	33120
	Oxidation Ditch	33130
	Aerated Lagoon	33140
	Facultative Lagoon	33150
	Aerobic Pond	33160
	Facultative Pond	33170
	UASB	33210
Tertiary Treatment	Chlorination	34110
	Rapid Gravity Filter	34220
Sludge Treatment	Gravity Thickening	35110
	Aerobic Digestion	35210
	Anaerobic Digestion	35220
	Sludge Drying beds	35310
	Filter Press	35320

The algorithms of the package can be broadly divided into following main heads:

- Package access code, cover page and general utilities.
- Menu generation and selection of the process unit.
- Analysis and/or design of selected option.
- Generation of digital and graphical output and queuing the units in its proper place in the treatment chain.
- Display of graphical information
- Saving of graphical information on a file in the user area for future reference and retrieval.

For speedy processing and to avoid any memory problem, the entire package is made up of small different programs, which are executed with proper control through a batch file in MS DOS environment (ver 3.3 or later). The package requires some files of Turbo C compiler to show the graphical outputs.

4.3 Menu Structure

The present work has been started to prepare a comprehensive software package for environmental engineering practice and education. Accordingly menu structure has been designed to include almost every aspect dealing from air pollution control to solid waste management, water supply to wastewater management. The overall menu structure is schematically presented in Figures 4.2 – 4.22.

For the sake of clarity and simplicity the entire screen display has been divided into two parts. The top part of the screen consists of selectable options available at that level, while bottom part is a operating menu, which is instrumental in accessing the package operation. The details of operating menu are shown in Figure 4.23.

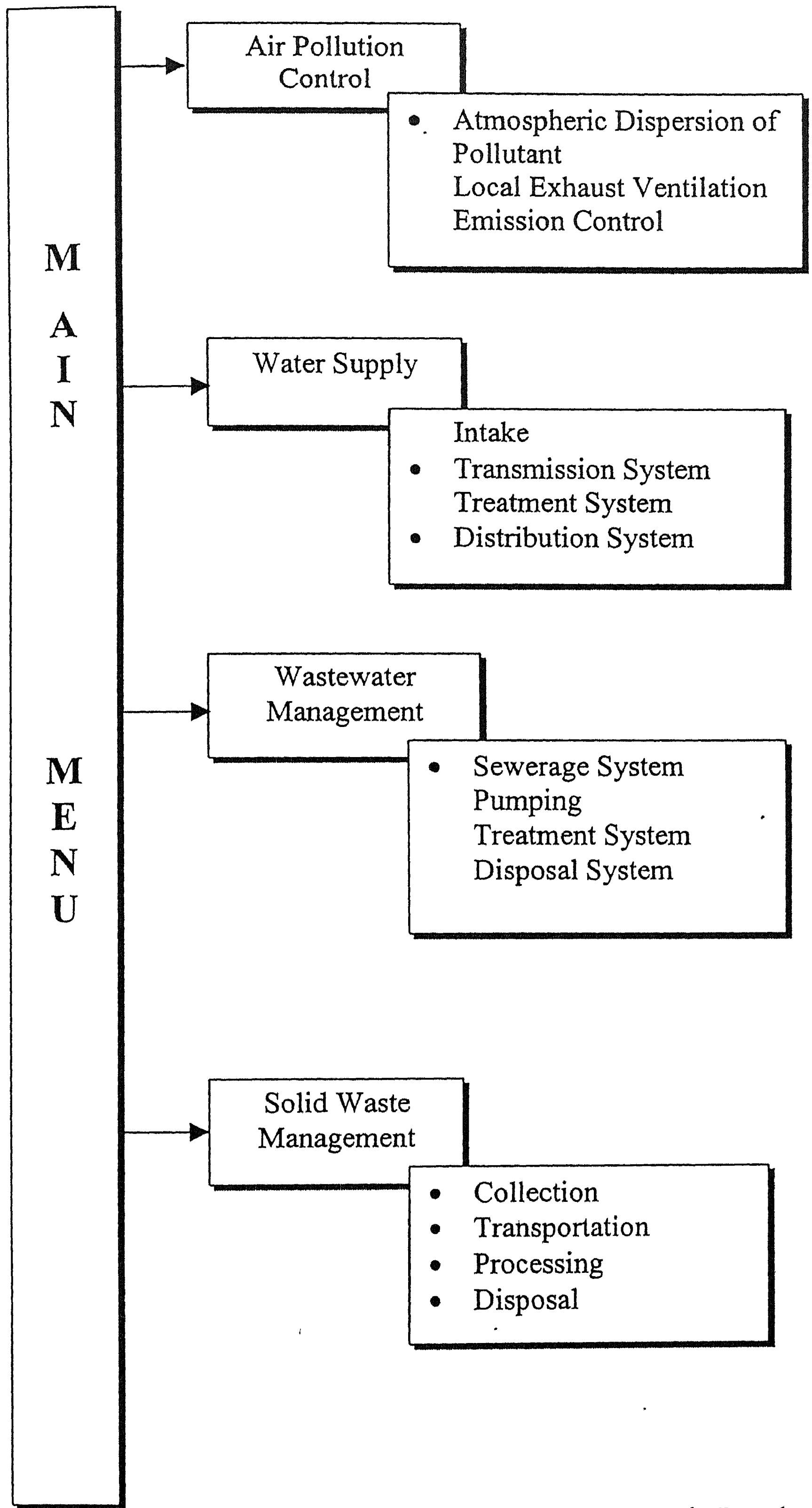

Figure 4.2: Options at Main Level

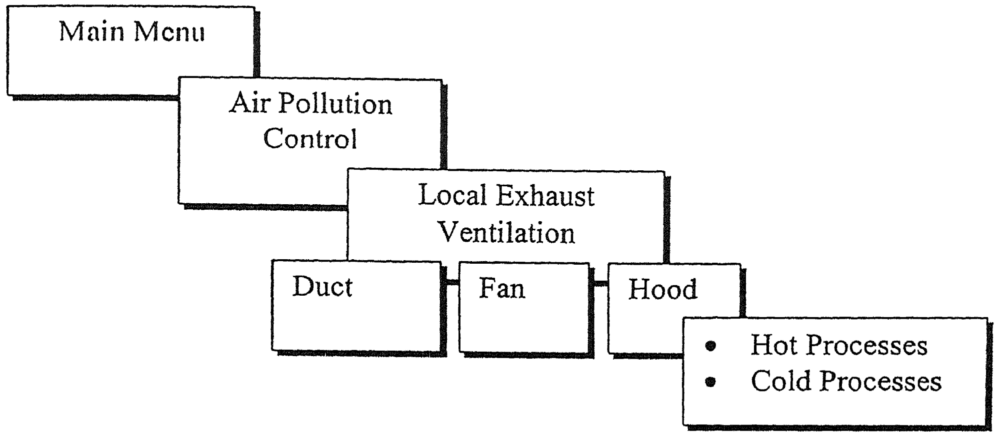

Figure 4.3: Options at Local Exhaust Ventilation System

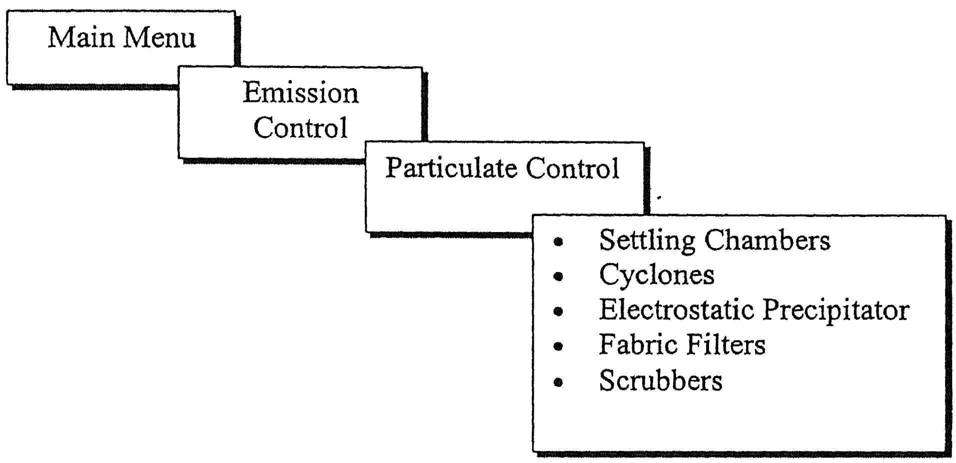

Figure 4.4: Options at Particulate Emission Control

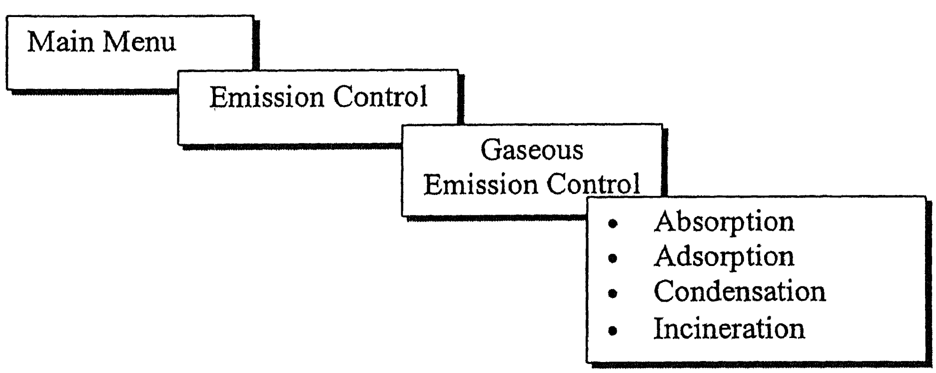

Figure 4.5: Options at Gaseous Emission Control

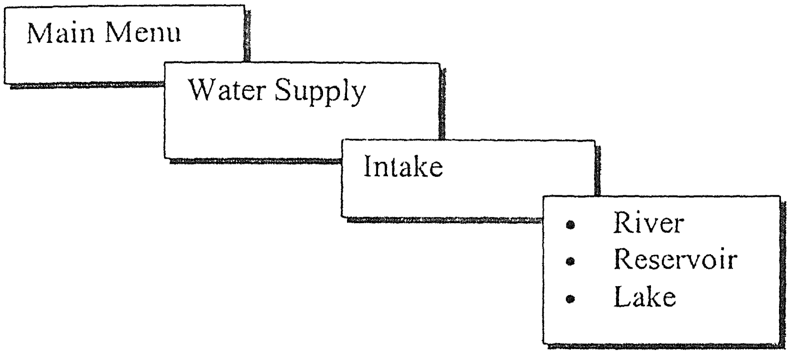

Figure 4.6: Options at Intake Level

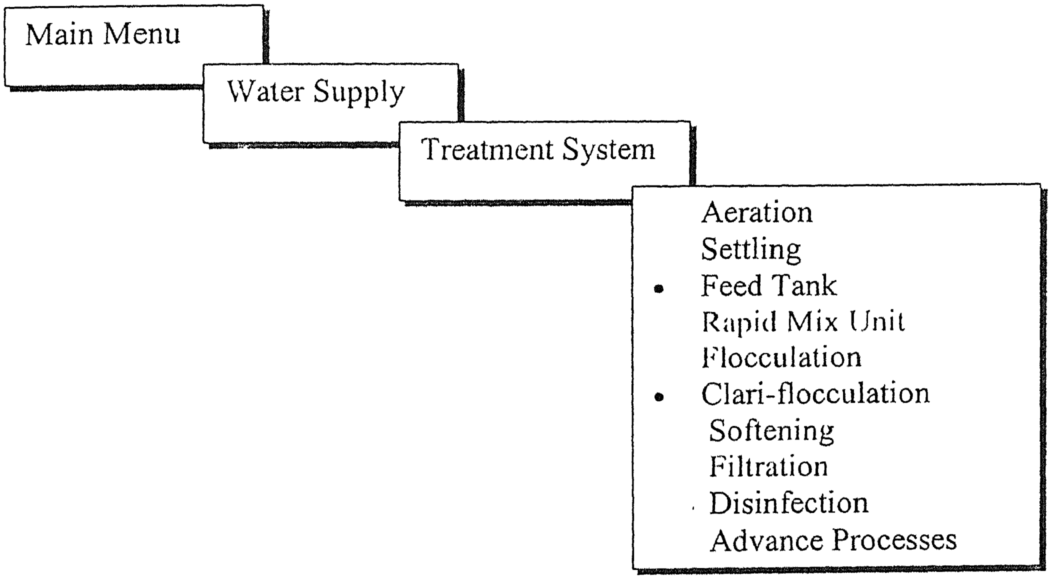

Figure 4.7: Options at Water Treatment System Level

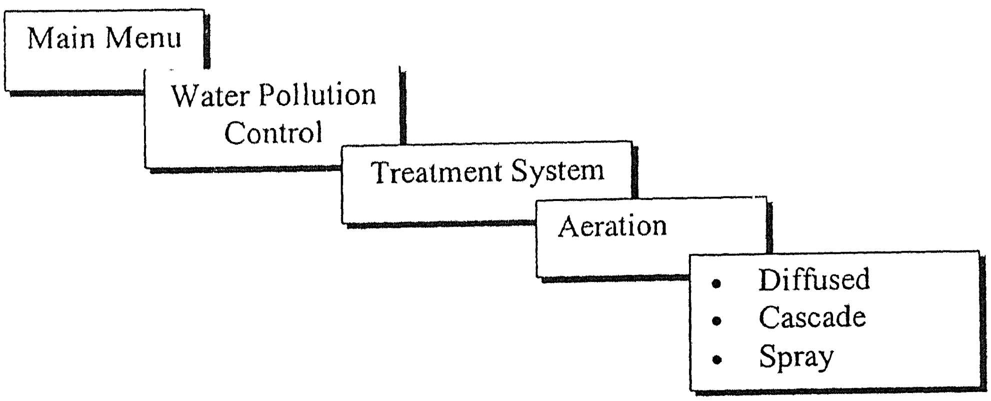

Figure 4.8: Options at Aeration Level

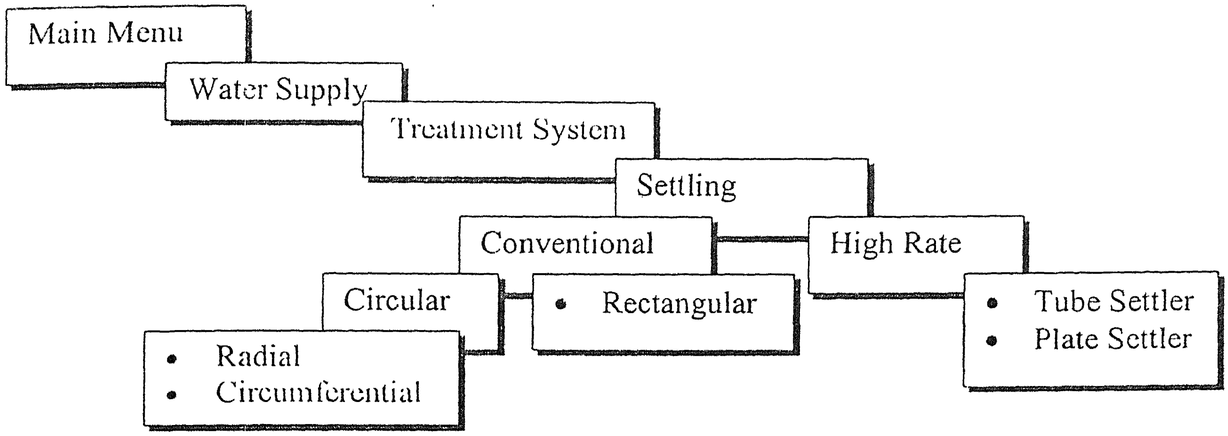

Figure 4.9: Options at Settling Level

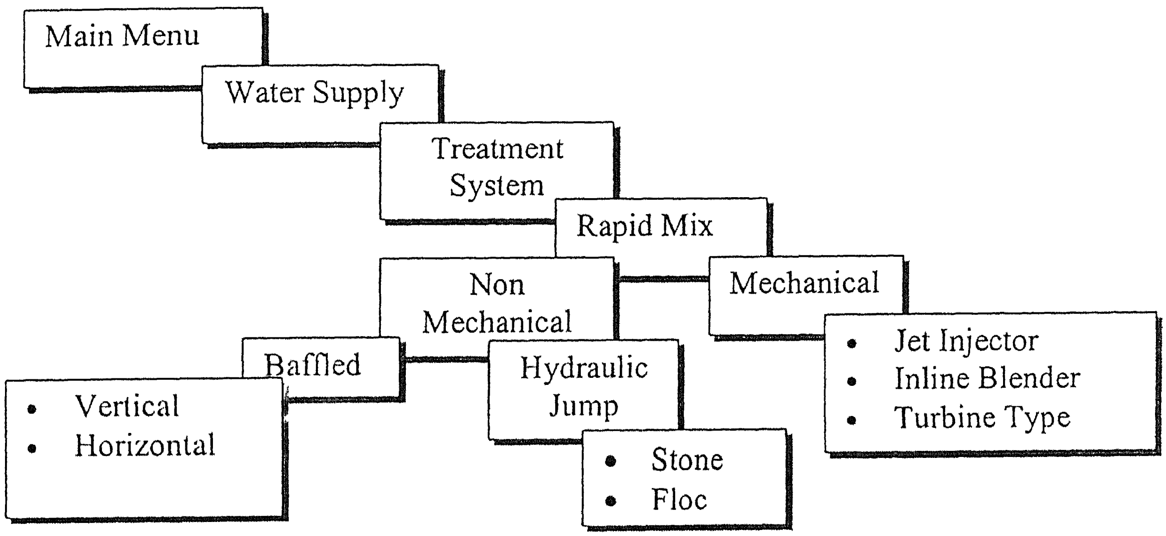

Figure 4.10: Options at Rapid Mix Level

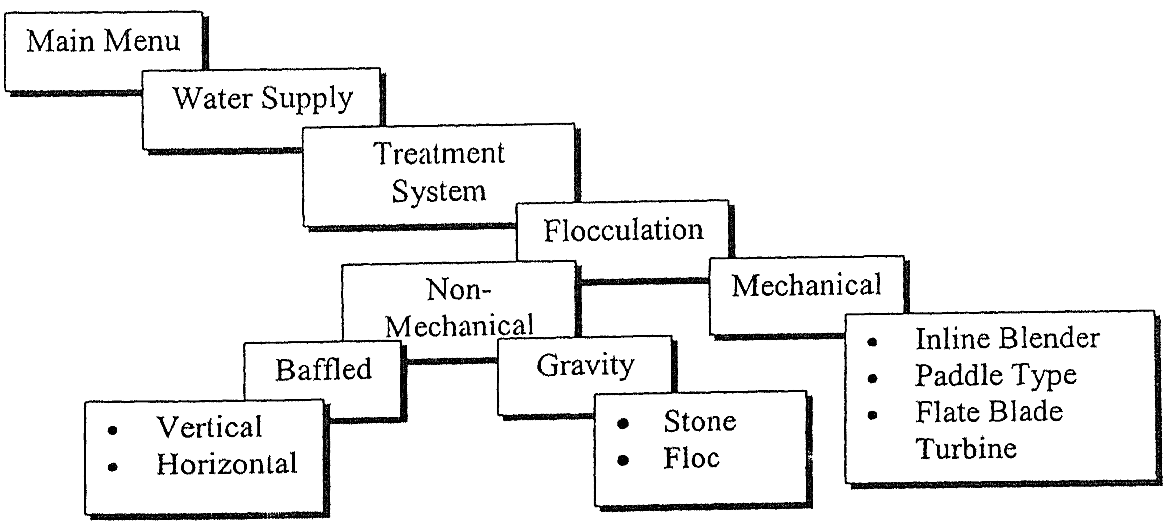

Figure 4.11: Options at Flocculation Level

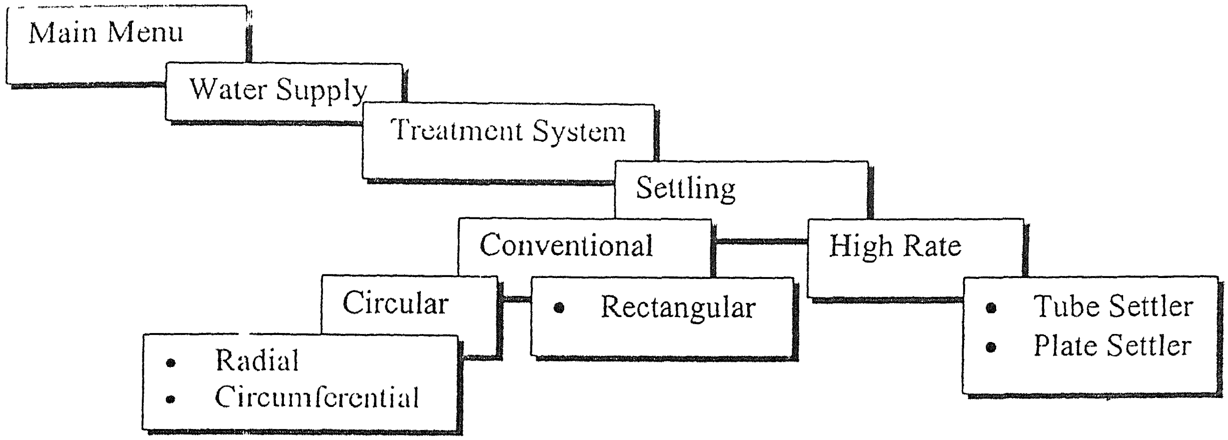

Figure 4.9: Options at Settling Level

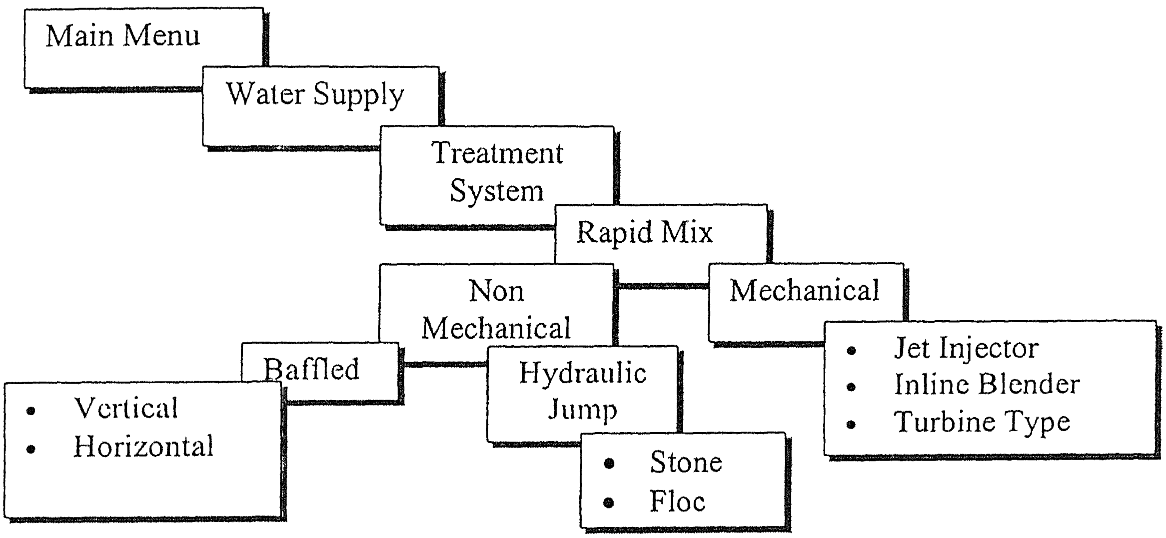

Figure 4.10: Options at Rapid Mix Level

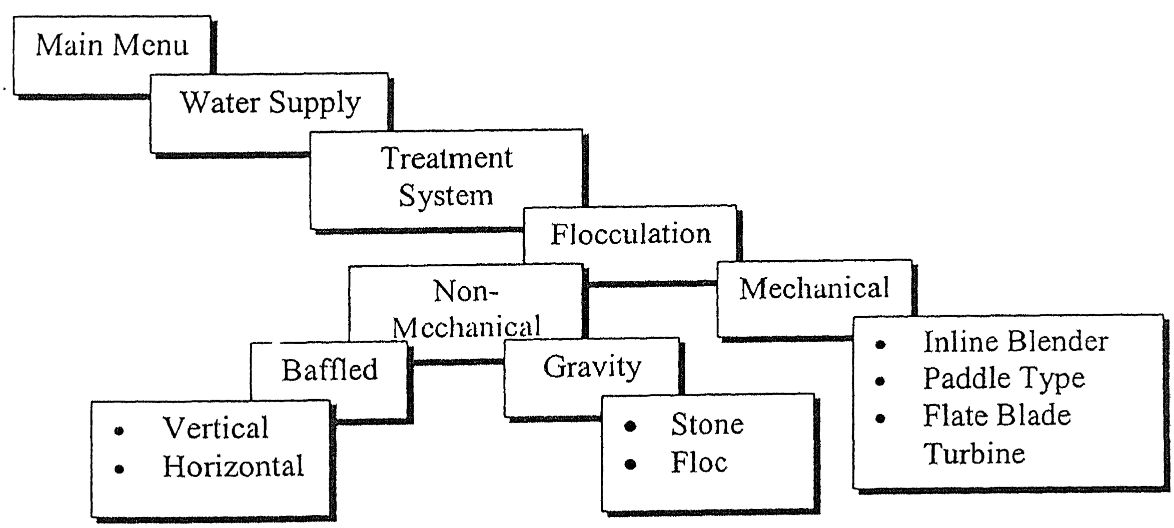

Figure 4.11: Options at Flocculation Level

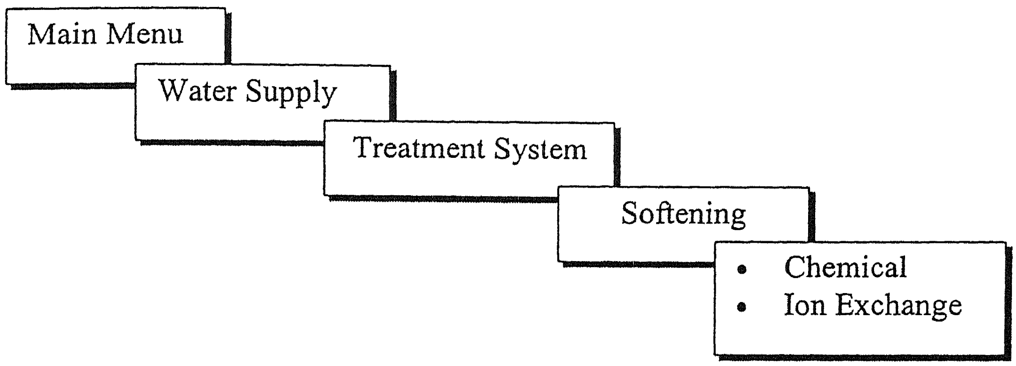

Figure 4.12: Options at Softening Level

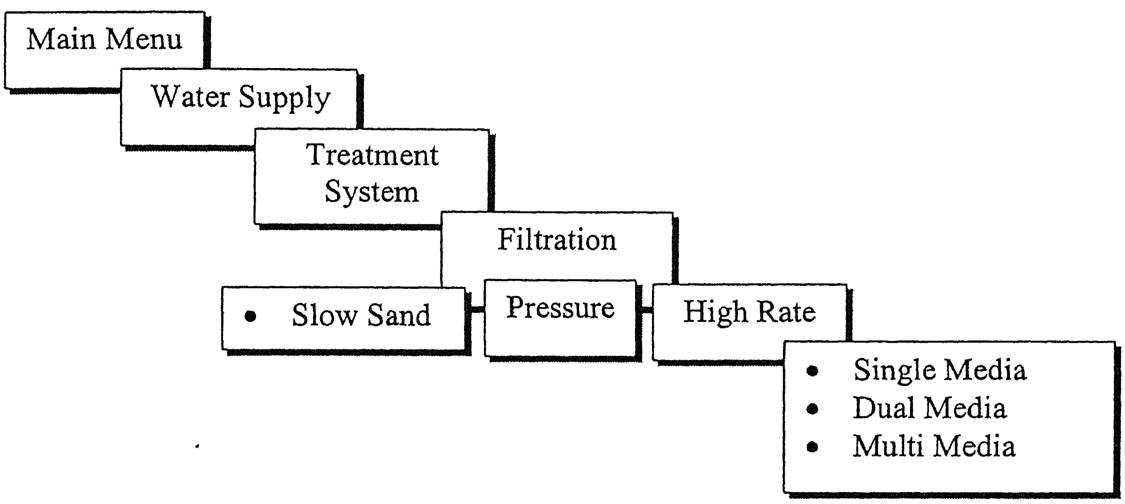

Figure 4.13: Options at Filtration Level

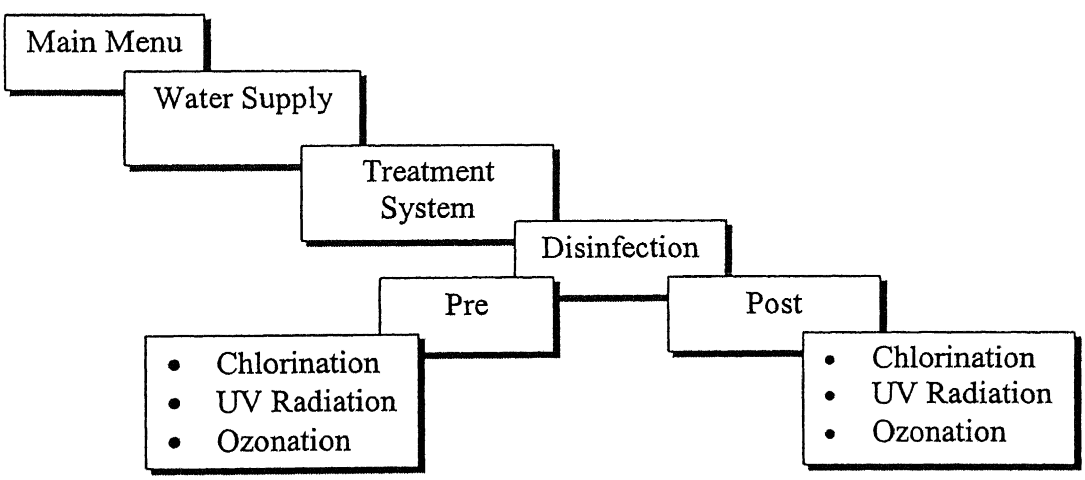

Figure 4.14: Options at Disinfection Level

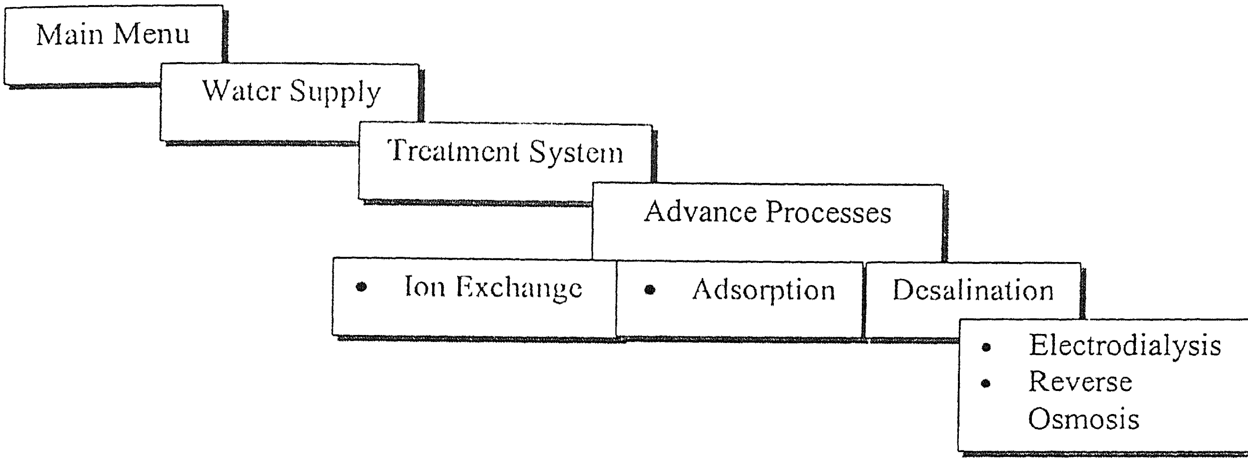

Figure 4.15: Options at Advance Processes Level

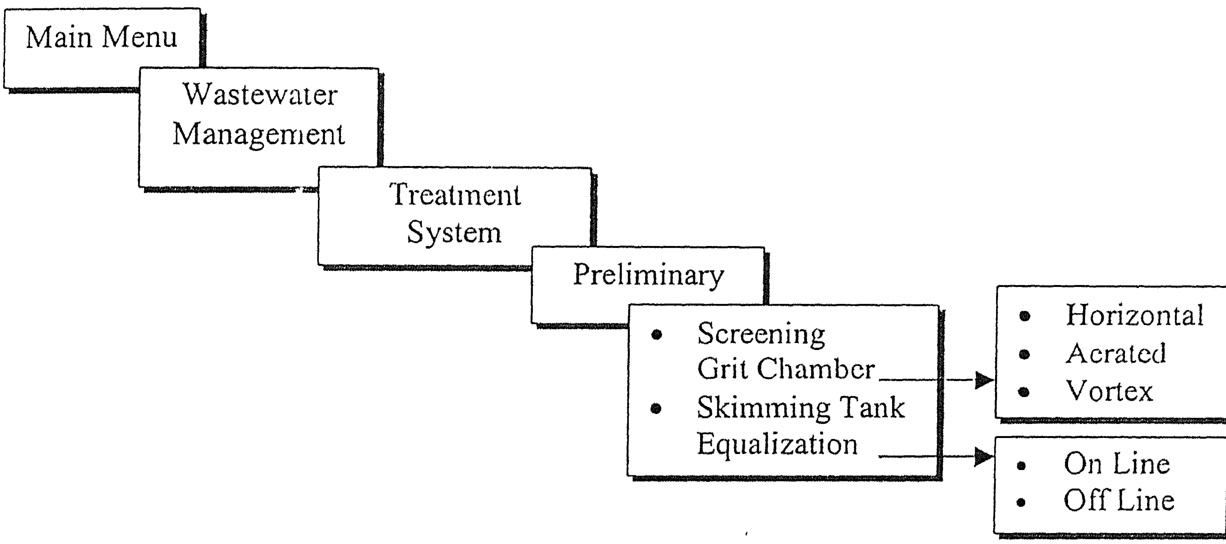

Figure 4.16: Options at Preliminary Treatment Level

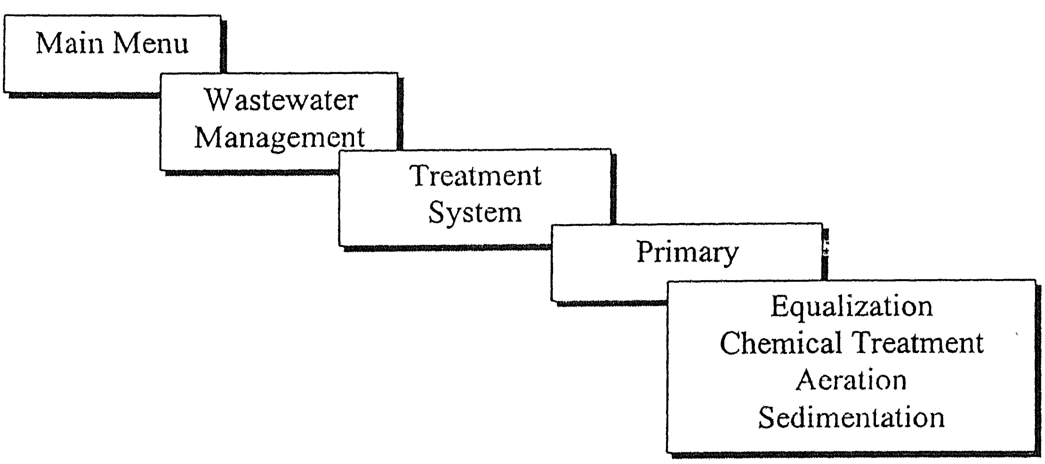

Figure 4.17: Options at Primary Treatment Level

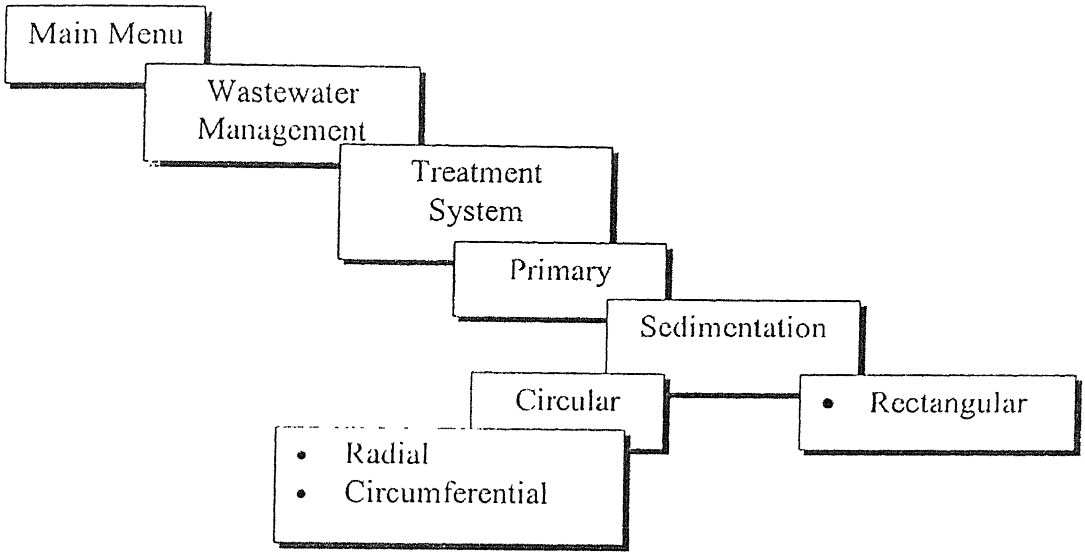

Figure 4.18: Options at Sedimentation Level

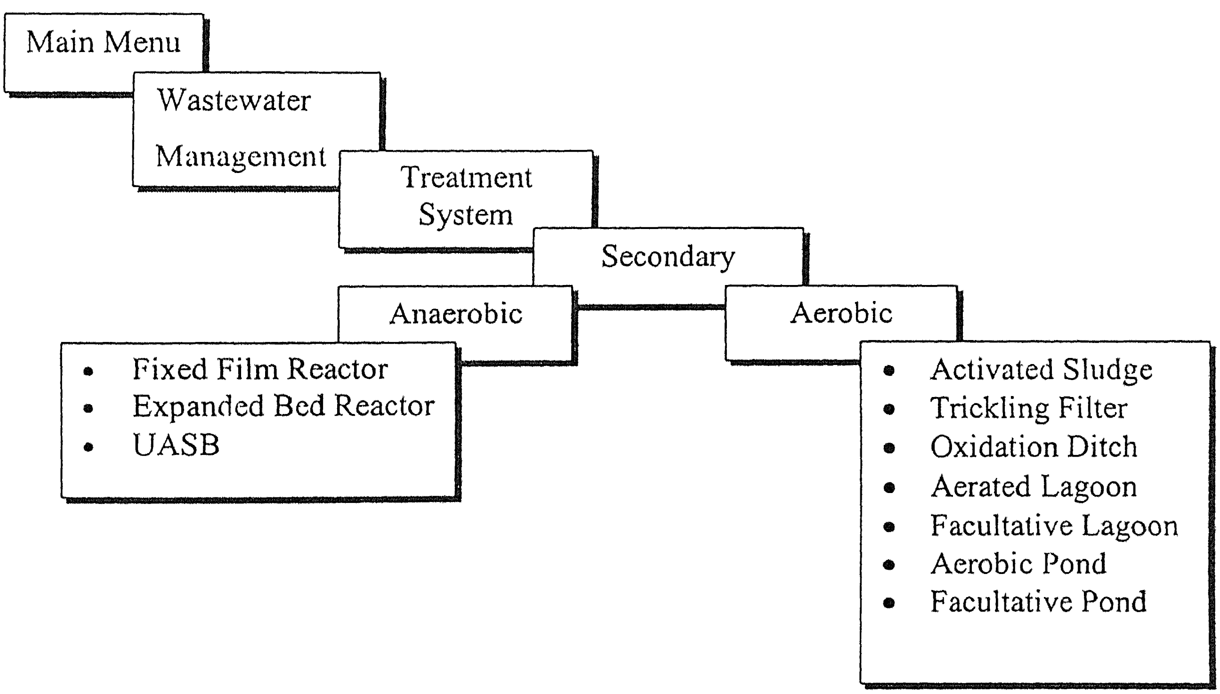

Figure 4.19: Options at Secondary Treatment Level

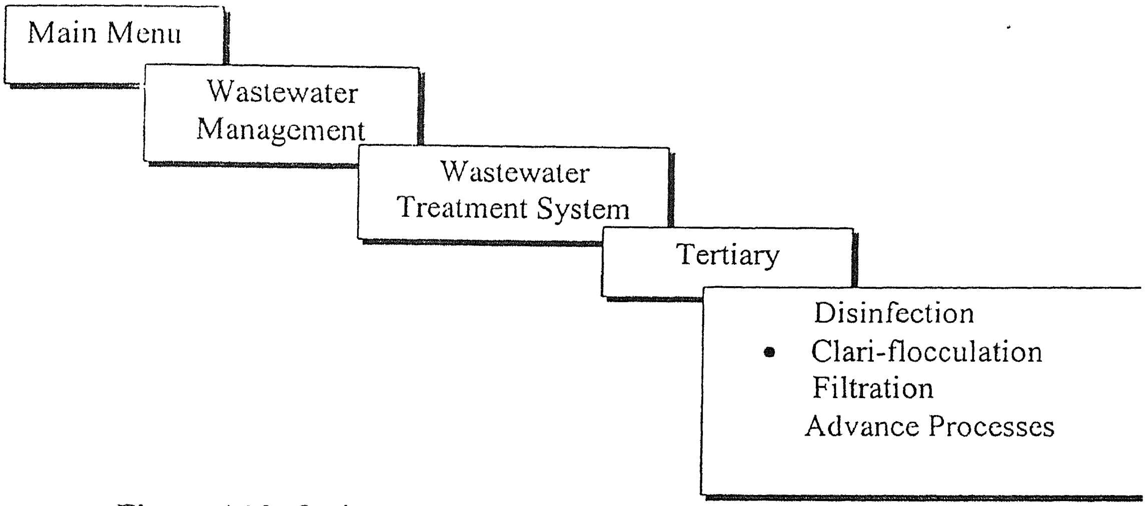

Figure 4.20: Options at Tertiary Treatment Level

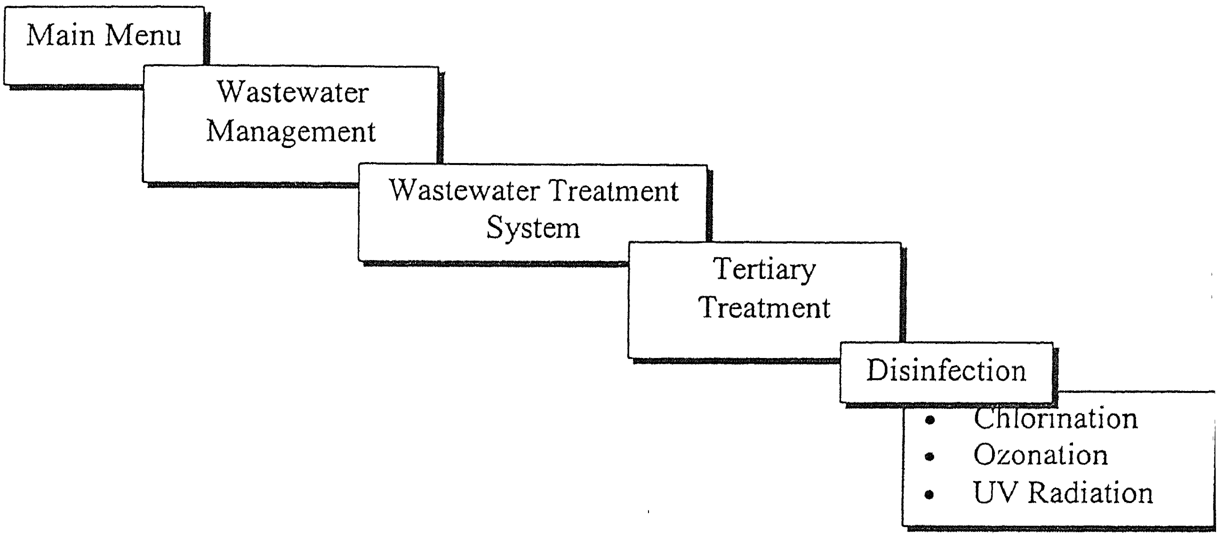

Figure 4.21: Options at Disinfection Level

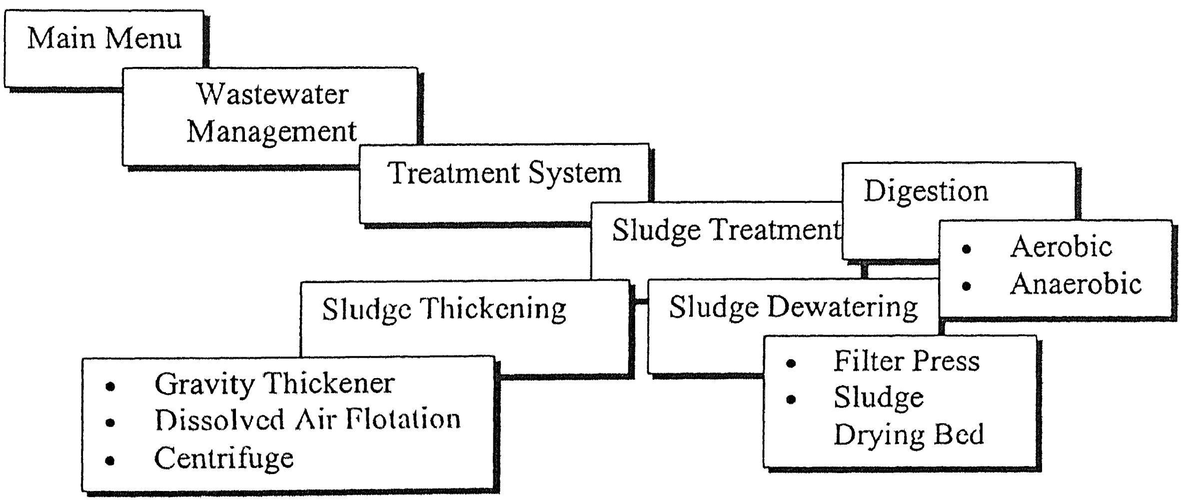

Figure 4.22: Options at Sludge Treatment Level

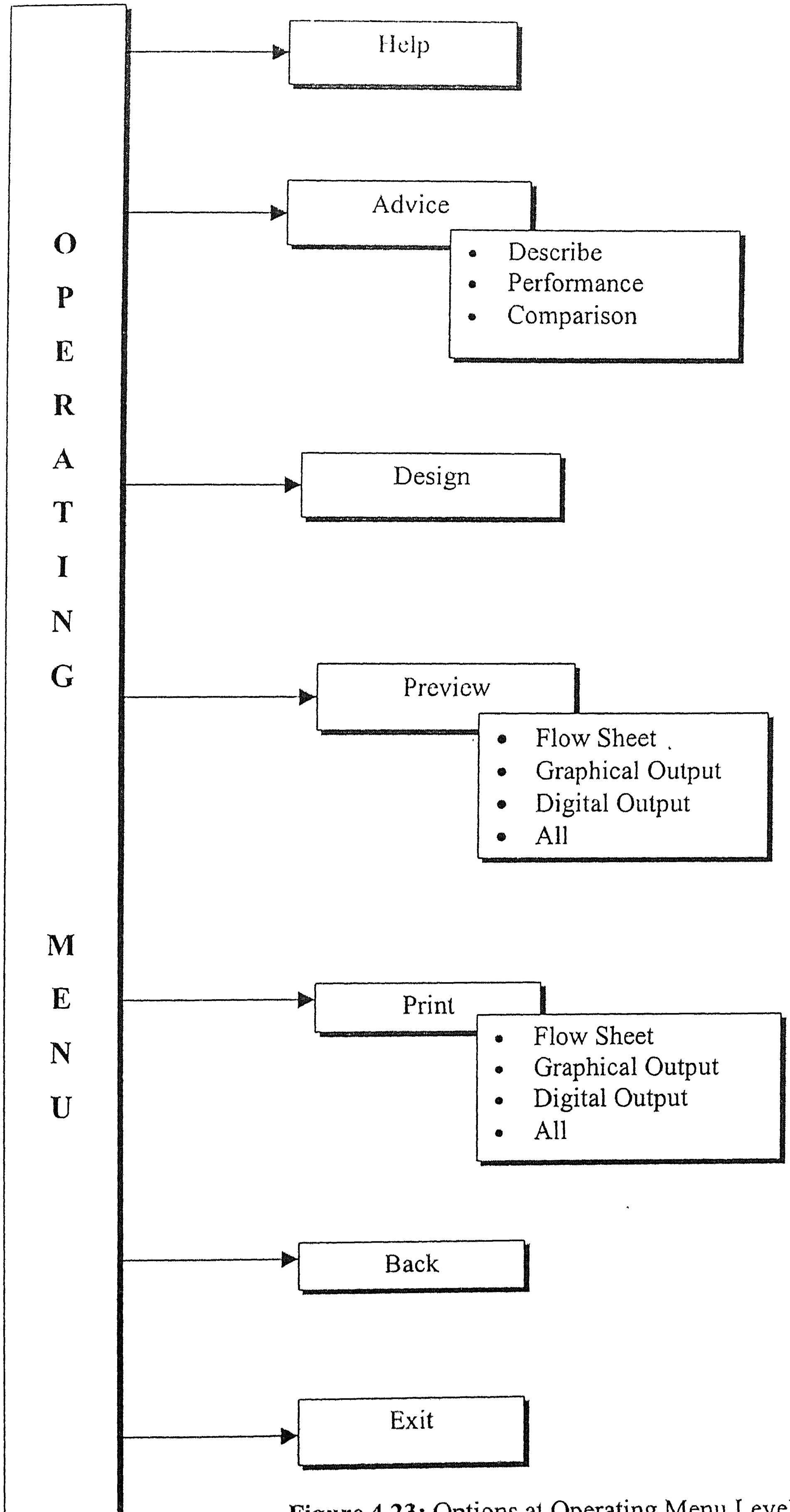

Figure 4.23: Options at Operating Menu Level

4.4 Structure of Advice

The option ADVICE is included in this package to equip the user with an on-line guidance for selection of options. It is designed in such a manner that it enables to quickly evaluate and rate the option against users requirement.

On invoking this option the text of advice is read from the Turbo C files with extension *.hlp and displayed on screen. The advice option is further subdivided into three sub options namely DESCRIBE: a brief description of (un)favorable conditions for operation, PERFORMANCE: performance from the point of view of important and pertinent design parameters, and COMPARISON: a critical comparison of options from the point of view of operating features. The relative grading levels and abbreviations used in ADVICE are given in Table 4.4.

Table 4.4: Ralative Grading Levels and Abbreviations used in ADVICE

0	Nil	2	Very Low	4	Low
6	Average	8	High	10	Very High
F	Very Poor	E	Poor	D	Fair
C	Good	B	Very Good	A	Excellent
NA:	Information Not Available				
N/A:	Not Applicable				

5 Design Methodologies – I: Air pollution control

In this chapter design algorithms of local exhaust ventilation system and emission control devices have been dealt. To formulate the design approach, air pollution engineering manual has been given the prime importance. But, in certain cases, where manual did not elaborate the design approach, standard text books and journals like Buonicore and Theodore (1975; 1976), Coulson and Richardson (1978), Goodfellow (1985), Wark and Warner (1981), Vaart *et al.* (1991), etc., have been used to formulate the algorithm.

5.1 Local Exhaust Ventilation System

The elements of local exhaust ventilation system include hoods, ducts and fan. The prime motive of providing local exhaust ventilation system is to collect the contaminant from the place of origin and convey it either to emission control units or discharge it to atmosphere through high stacks,

5.1.1 Design of Hoods

Hoods are devices used to capture emissions of heat or air contaminants, which are then conveyed through exhaust system ductwork to a more convenient discharge point or to air pollution control equipment. The quantity of air required to capture and convey the air contaminants depends upon size and shape of the hood, its position/relation to the point of emission, and the nature and quantity of the air contaminant.

Hoods can be classified into two groups depending upon the heat generation during the process, (i) Hoods for Cold Processes, and (ii) Hoods for Hot Processes.

5.1.1a Design of Hoods for Cold Processes

In design of hoods for cold processes, a large body of recommended ventilation rates are used, which have been built over the years by various groups and organizations who are involved in control of air contaminant.

i) Abrasive Blast Room

1. Input: Area of Openings in Room, A_{op}^{ch}; Width of Room, W_r^{ch}; Height of Room, H_r^{ch}; Downdraft Velocity, $\dot{v}_{dd}^{ch}$; Cross-draft Velocity, v_{cd}^{ch}.
2. Compute Required Exhaust Rate w.r.t. Area of Openings in Room and Cross-sectional Area and Design Exhaust Rate. Use Equation Block 5-001.
3. Display Area of Openings in Room, Width of Room, Height of Room and Design Exhaust Rate.

DEFAULT VALUES

$v_{dd}^{ch} = 0.41$ m/s, $v_{cd}^{ch} = 0.51$ m/s.

EQUATION BLOCK 5-001

1. $Q_{op}^{ch} = v_{dd}^{ch} \text{ x } A_{op}^{ch}$
2. $Q_{cse}^{ch} = v_{dc}^{ch} \text{ x } W_r^{ch} \text{ x } H_{rm}^{ch}$
3. Q_d^{ch} = Greater of above Two Exhaust Rates

UNITS

Q_{op}^{ch}, m^3/s; Q_{cs}^{ch}, m^3/s; Q_d^{ch}, m^3/s

ii) Abrasive Blast Cabinet

1. Input: Area of Openings in Cabinet, A_{op}^{ch}; Width of Cabinet, W_{cb}^{ch}; Length of Cabinet, L_{cb}^{ch}; Height of Cabinet, H_{cb}^{ch}; Velocity of Air through Openings, v_{op}^{ch}; Rate of Air Change per Minute, R_{ac}^{ch}.
2. Compute Exhaust Rate w.r.t. Area of Openings and Air Change per Minute and Design Exhaust Rate. Use Equation Block 5-002.

3. Display Area of Openings in Cabinet, Width of Cabinet, Length of Cabinet, Height of Cabinet and Design Exhaust Rate.

DEFAULT VALUES

$v_{op}^{ch} = 2.54$ m/s, $R_{ac}^{ch} = 20$

EQUATION BLOCK 5-002

1. $Q_{op}^{ch} = v_{op}^{ch} \times A_{op}^{ch}$.
2. $Q_{acm}^{ch} = R_{ac}^{ch} \times W_{cb}^{ch} \times L_{cb}^{ch} \times H_{cb}^{ch}/60$
3. Q_{d}^{ch} = Greater of above Two Exhaust Rates

UNITS

Q_{op}^{ch}, m^3/s; Q_{acm}^{ch}, m^3/s; Q_{d}^{ch}, m^3/s;

iii) Bagging Machines

1. Input: Area of Openings in Booth, A_{op}^{ch}; Enclosure Velocity of Air through Openings, v_{op}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-003.
3. Display Area of Openings in Booth or Enclosure, Design Exhaust Rate.

DEFAULT VALUES

v_{op}^{ch} (Paper Bags) = 0.51 m/s, v_{op}^{ch} (Cloth Bags) = 1.02 m/s.

EQUATION BLOCK 5-003

1. $Q_{d}^{ch} = v_{op}^{ch} \times A_{op}^{ch}$

UNITS

Q_{d}^{ch}, m^3/s;

iv) Belt Conveyer

1. Input: Area of Openings, A_{op}^{ch}; Belt Speed, v_{b}^{ch}; Belt Width, W_{bs}^{ch}; Velocity of Air through Openings, v_{op}^{ch}; Exhaust Rate per Unit Belt Width, Q_{be}^{ch}.
2. Compute Exhaust Rate w.r.t Area of Openings and Belt Width and Design Exhaust Rate. Use Equation Block 5-004.
3. Display Area of Openings, Belt Speed, Belt Width and Design Exhaust Rate.

DEFAULT VALUES

$v_b^{ch} = 1.0$ m/s, $v_{op}^{ch} = 0.76$ m/s, $Q_{be}^{ch} = 0.54$ m³/s/m

EQUATION BLOCK 5-004
1. $Q_{op}^{ch} = v_{op}^{ch} \times A_{op}^{ch}$.
2. $Q_b^{ch} = Q_{be}^{ch} \times W_{bs}^{ch}$
3. Q_d^{ch} = Greater of above Two Exhaust Rates.
UNITS
Q_{op}^{ch}, m³/s; Q_b^{ch}, m³/s; Q_d^{ch}, m³/s;

v) Bucket Elevator

1. Input: Area of Cross-section of Casing, A_{cs}^{ch}; Exhaust Rate per Unit Cross-sectional Area of Elevator Casing, Q_{cse}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-005.
3. Display Area of Cross-section of Casing and Design Exhaust Rate.

DEFAULT VALUES

$Q_{cse}^{ch} = 0.51$ m³/s/m²

EQUATION BLOCK 5-005
1. $Q_d^{ch} = Q_{cse}^{ch} \times A_{cs}^{ch}$
UNITS
Q_d^{ch}, m³/s;

vi) Foundry Screen

1. Input: Area of Opening in Enclosure, A_{op}^{ch}; Area of Cross-section, A_{cs}^{ch}; Velocity of Air through Openings, v_{op}^{ch}; Exhaust Rate per Unit Cross-sectional Screen Area, Q_{cse}^{ch}.
2. Compute Exhaust Rate w.r.t. Area of Openings in Enclosure and Area of Cross-section and Design Exhaust Rate. Use Equation Block 5-006.

3. Display Area of Openings in Enclosure, Area of Cross-section and Design Exhaust Rate.

DEFAULT VALUES

v_{op}^{ch} (Cylindrical) = 2.03 m/s, v_{op}^{ch} (Flat Deck) = 1.02 m/s, Q_{cse}^{ch} (Cylindrical) = 0.51 $m^3/s/m^2$, Q_{cse}^{ch} = 0.13 $m^3/s/m^2$.

EQUATION BLOCK 5-006

1. $Q_{op}^{ch} = v_{op}^{ch} \times A_{op}^{ch}$
2. $Q_{cs}^{ch} = Q_{cse}^{ch} \times A_{cs}^{ch}$
3. Q_d^{ch} = Maximum of above Two Values.

UNITS

Q_{op}^{ch}, m^3/s; Q_{cs}^{ch}, m^3/s; Q_d^{ch}, m^3/s;

vii) Foundry Shakeout

1. Input: Area of Openings, A_{op}^{ch}; Grate Area, A_g^{ch}; Velocity of Air through Openings, v_{op}^{ch}; Exhaust Rate per Unit Grate Area, Q_{ge}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-007.
3. Display Area of Openings, Grate Area and Design Exhaust Rate.

DEFAULT VALUES

v_{op}^{ch}= 1.02 m/s, Q_{ge}^{ch} (Hot Castings) = 1.02 $m^3/s/m^2$, Q_{ge}^{ch} (Cool Castings) = 0.76 $m^3/s/m^2$.

EQUATION BLOCK 5-007

1. $Q_{op}^{ch} = v_{op}^{ch} \times A_{op}^{ch}$
2. $Q_g^{ch} = Q_{ge}^{ch} \times A_g^{ch}$
3. Q_d^{ch} = Maximum of above Two Exhaust Rates.

UNITS

Q_{op}^{ch}, m^3/s; Q_g^{ch}, m^3/s; Q_d^{ch}, m^3/s;

viii) Fondry Shakeout (Side Hood)

1. Input: Grate Area, A_g^{ch}; Exhaust Rate per Unit Grate Area, Q_{ge}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-008.
3. Display Grate Area and Design Exhaust Rate.

DEFAULT VALUES

Q_{ge}^{ch} (Hot Castings) = 2.29 $m^3/s/m^2$, Q_{ge}^{ch} (Cold Castings) = 1.91 $m^3/s/m^2$.

EQUATION BLOCK 5-008

1. $Q_d^{ch} = Q_{ge}^{ch} \times A_g^{ch}$

UNITS

Q_d^{ch}, m^3/s;

ix) Grinder, Disc & Portable

1. Input: Area of Open Face, A_{op}^{ch}; Plan Working Area, A_{pl}^{ch}; Velocity of Air through Open Face, v_{op}^{ch}; Exhaust Rate per Unit Plan Working Area, Q_{ple}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-009.
3. Display Area of Open Face, Plan Working Area and Design Exhaust Rate.

DEFAULT VALUES

$v_{op}^{ch} = 1.52$ m/s, $Q_{ple}^{ch} = 0.76$ $m^3/s/m^2$.

EQUATION BLOCK 5-009

1. $Q_{op}^{ch} = v_{op}^{ch} \times A_{op}^{ch}$.
2. $Q_{pl}^{ch} - Q_{ple}^{ch} \times A_{pl}^{ch}$.
3. Q_d^{ch} = Greater of the Above Two Exhaust Rates.

UNITS

Q_{op}^{ch}, m^3/s; Q_{pl}^{ch}, m^3/s; Q_d^{ch}, m^3/s;

x) Grinders and Crushers

1. Input: Area of Openings, A_{op}^{ch}; Velocity of Air through Openings, v_{op}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-010.
3. Display Area of Openings, Design Exhaust Rate.

DEFAULT VALUES

$v_{op}^{ch} = 1.02$ m/s

EQUATION BLOCK 5-010

1. $Q_d^{ch} = v_{op}^{ch} \text{ x } A_{op}^{ch}$.

UNIT

Q_d^{ch}, m^3/s;

xi) Mixer

1. Input: Area of Openings, A_{op}^{ch}; Velocity of Air Through Openings, v_{op}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-011.
3. Display Area of Openings and Design Exhaust Rate.

DEFAULT VALUES

$v_{op}^{ch} = 0.76$ m/s.

EQUATION BLOCK 5-011

1. $Q_d^{ch} \quad v_{op}^{ch} \text{ x } A_{op}^{ch}$.

UNIT

Q_d^{ch}, m^3/s;

xii) Packaging Machine (Booth)

1. Input: Width of Booth, W_{bt}^{ch}; Height of Booth, H_{bt}^{ch}; Distance of Work-piece from Face of Booth, x_{wb}^{ch}; Indraft Velocity, v_{id}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-012.
3. Display Width of Booth, Height of Booth, Distance of Work-piece from Face of Booth and Design Exhaust Rate.

DEFAULT VALUES

$v_{id}^{ch} = 0.38$ m/s,

EQUATION BLOCK 5-012

1. $Q_d^{ch} = v_{id}^{ch} \times [10 \times (x_{wb}^{ch})^2 + 2 \times (W_{bt}^{ch} \times H_{bt}^{ch})]/2$

UNIT

Q_d^{ch}, m^3/s;

xiii) Packaging Machine (Downdraft/Enclosure)

1. Input: Area of Openings, A_{op}^{ch}; Velocity of Air Through Openings, v_{op}^{ch}.
2. Compute Design Exhaust Rates. Use Equation Block 5-013.
3. Display Area of Openings and Design Exhaust Rate.

DEFAULT VALUES

v_{op}^{ch} (Downdraft) = 0.57 m/s, v_{op}^{ch} (Enclosure) = 1.27 m/s,

EQUATION BLOCK 5-013

1. $Q_d^{ch} = v_{op}^{ch} \times A_{op}^{ch}$.

UNIT

Q_d^{ch}, m^3/s;

xiv) Paint Spray

1. Input: Width of Booth, W_{bt}^{ch}; Height of Booth, H_{bt}^{ch}; Distance of Work-piece from Face of Booth, x_{wb}^{ch}; Indraft Velocity, v_{id}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-014.
3. Display Width of Booth, Height of Booth, Distance of Work-piece from Face of Booth and Design Exhaust Rate.

DEFAULT VALUES

v_{id}^{ch} = 0.76 m/s.

EQUATION BLOCK 5-014

1. $Q_d^{ch} = v_{id}^{ch} \times [10 \times (x_{wb}^{ch})^2 + 2 \times (W_{bt}^{ch} \times H_{bt}^{ch})]/2$

UNIT

Q_d^{ch}, m^3/s;

xv) Rubber Rolls

1. Input: Area of Openings, A_{op}^{ch}; Velocity of Air Through Openings, v_{op}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-015.
3. Display Area of Openings and Design Exhaust Rate.

DEFAULT VALUES

v_{op}^{ch}= 0.45 m/s.

EQUATION BLOCK 5-015

1. $Q_d^{ch} = v_{op}^{ch} \times A_{op}^{ch}$

UNIT

Q_d^{ch}, m^3/s;

xvi) Welding Arc

1. Input: Width of Booth, W_{bt}^{ch}; Height of Booth, H_{bt}^{ch}; Distance of Work-piece from Face of Booth, x_{wb}^{ch}; Velocity of Air Through Opening, v_{op}^{ch}.
2. Compute Design Exhaust Rate. Use Equation Block 5-016.
3. Display Width of Booth, Height of Booth, Distance of Work-piece from Face of Booth and Design Exhaust Rate.

DEFAULT VALUES

$v_{op}^{ch} = 0.51$ m/s

EQUATION BLOCK 5-016

1. $Q_d^{ch} = v_{op}^{ch} \times [10 \times (x_{wb}^{ch})^2 + 2 \times (W_{bt}^{ch} \times H_{bt}^{ch})]/2$

UNIT

Q_d^{ch}, m^3/s;

5.1.1b Hoods for Hot Processes

Hooding for hot processes requires application of different principie than that for cold processes because of the thermal effect. A thermal draft is caused due to significant heat transfer to the surroundings, causing a rising air air current with

considerable velocity. The higher the column rises, the larger it becomes and the more diluted with ambient air. The design of hood for hot processes takes into account all these things.

The hoods for hot processes can be further classified into four types as (i) circular high canopy hood, (ii) rectangular high canopy hood, (iii) circular low canopy hood, and (iv) rectangular low canopy hood.

i) Circular High Canopy Hood

1. Input: Diameter of Source, d_{so}^{hh}; Temperature of Source, T_{hs}^{hh}; Height of Hood Above Source, H_{hs}^{hh}; Temperature of Ambient Air, T_a^{hh}; Velocity Required in Remaining Area of Hood, v_{ra}^{hh}.
2. Compute Distance from Source to the Hypothetical Point Source, Distance from Hypothetical Point Source to Hood, Diameter of Rising Air Stream, Required Hood Diameter, Area of Hood Face, Velocity of Rising Air Jet and Design Exhaust Rate. Use Equation Block 5-018.
3. Display Diameter of Hot Source, Temperature of Hot Source, Height of Hood Above Hot Source, Temperature of Ambient Air, Required Hood Diameter and Design Exhaust Rate.

EQUATION BLOCK 5-018

1. $x_{sp}^{hh} = (2 \times d_{so}^{hh}/0.3)^{1.138} \times 0.3$
2. $x_{hp}^{hh} = x_{sp}^{hh} + H_{hp}^{hh}$
3. $d_{as}^{hh} = 0.5 \times [x_{hp}^{hh}/0.3]^{0.88} \times 0.3$
4. $A_{ras}^{hh} = \pi \times (d_{as}^{hh})^2/4$
5. $d_h^{hh} = d_{as}^{hh} + 0.8 \times H_{hp}^{hh}$
6. $A_{hh}^{hh} = \pi \times (d_h^{hh})^2/4$
7. $v_{rh}^{hh} = 8 \times (A_{hh}^{hh}/(0.3)^2)^{1/3} \times [(T_h^{hh} - T_a) \times 18 + 32]^{5/12} \times 0.3/[(H_{hp}^{hh}/0.3)^{1/4} \times 60]$
8. $Q_d^{hh} = v_{rh}^{hh} \times A_{ras}^{hh} + v_{ra}^{hh} \times (A_{hh}^{hh} - A_{ras}^{hh})$

UNITS

x_{sp}^{hh}, m; x_{hp}^{hh}, m; d_{as}^{hh}, m; d_h^{hh}, m; A_{ras}^{hh}, m^2; A_{hh}^{hh}, m^2; v_{ra}^{hh}, m/s; Q_d^{hh}, m^3/s.

ii) Rectangular High Canopy Hood

1. Input: Length of Hot Source, L_{hs}^{hh}; Width of Hot Source, W_{hs}^{hh}; Temperature of Hot Source, T_h^{hh}; Height of Hood Above Hot Source, H_{hs}^{hh}; Temperature of Ambient Air, T_a; Velocity through Remaining Area, v_{ra}^{hh}.
2. Compute Distance of Hot Source from Hypothetical Point Source, Distance from Hypothetical Point Source to the Hood, Width of Rising Air Jet, Length of Rising Air Jet at Hood Face, Required Hood Width, Required Hood Length, Area of Hood Face, Velocity of Rising Air Jet at Hood Face and Design Exhaust Rate. Use Equation Block 5-019.
3. Display Length of Hot Source, Width of Hot Source, Temperature of Hot Source, Height of Hood above Hot Source, Temperature of Ambient Air, Required Hood Width, Required Hood Length and Design Exhaust Rate.

EQUATION BLOCK 5-019

1. $x_{sp}^{hh} = (2 \text{ x } W_{hs}^{hh}/0.3)^{1.138} \text{ x } 0.3$
2. $x_{hp}^{hh} = x_{sp}^{hh} + H_{hs}^{hh}$
3. $W_{ras}^{hh} = 0.5 \text{ x } (x_{hp}^{hh})^{0.88} \text{ x } 0.3$
4. $L_{ras}^{hh} = L_{hs}^{hh} + (W_{ras}^{hh} - W_{hs}^{hh})$
5. $A_{ras}^{hh} = W_{ras}^{hh} \text{ x } L_{ras}^{hh}$
6. $W_h^{hh} = W_{ras}^{hh} + 0.8 \text{ x } H_{hs}^{hh}$
7. $L_h^{hh} = L_{ras}^{hh} + 0.8 \text{ x } H_{hs}^{hh}$
8. $A_{hh}^{hh} = W_h^{hh} \text{ x } L_h^{hh}$
9. $V_{rh}^{hh} = 8 \text{ x } [(W_h^{hh} \text{ x } L_h^{hh})/(0.3 \text{ x } 0.3)]^{1/3} \text{ x } [(T_h^{hh} - T_a^{hh}) \text{ x } 1.8 + 32] \text{ x } 0.3/[(x_{hp}^{hh}/0.3)1/4 \text{ x } 60]$
10. $Q_d^{hh} = A_{ras}^{hh} \text{ x } v_{rh}^{hh} + v_{ra}^{hh} \text{ x } (A_{hh}^{hh} - A_{ras}^{hh})$

UNITS

x_{hsp}^{hh}, m; x_{hp}^{hh}, m; W_{ras}^{hh}, m; L_{ras}^{hh}, m; W_h^{hh}, m; L_h^{hh}, m; A_{ras}^{hh}, m^2; A_{hh}^{hh}, m^2; v_{ras}^{hh}, m/s; Q_d^{hh}, m^3/s.

iii) Low Canopy Circular Hoods

1. Input: Diameter of Hot Source, d_{hs}^{hh}; Temperature of Hot Source, T_h^{hh}; Height of Hood Above Hot Source, H_{hs}^{hh}; Ambient Air Temperature, T_a.

2. Compute Temperature Difference, Diameter of Hood and Design Exhaust Rate. Use Equation Block 5-020.
3. Display Diameter of Hot Source, Diameter of Hood, Temperature of Hot Source, Ambient Air Temperature, Height of Hood above Hot Source and Design Exhaust Rate.

EQUATION BLOCK 5-020

1. $\Delta t = T_h^{hh} \quad T_a$
2. $d_h^{hh} = d_{hs}^{hh} + 0.3$
3. $Q_d^{hh} = 4.70 \times (d_h^{hh}/0.3)^{2.33} \times (\Delta t \times 1.8 + 32)^{5/12} \times (0.3)^3/60$

UNITS

Δt, ^0c; d_h^{hh}, m; Q_d^{hh}, m^3/s;

iv) Low Canopy Rectangular Hood

1. Input: Width of Hot Source, W_{hs}^{hh}; Length of Source, L_{hs}^{hh}; Temperature of Hot Source, T_h^{hh}; Height of Hood above Hot Source, H_{hs}^{hh}; Ambient Air Temperature, T_a.
2. Compute Width of Hood, Length of Hood, Temperature Difference and Design Exhaust Rate. Use Equation Block 5-021.
3. Display Width of Source, Length of Source, Height of Hood above the Source, Width of Hood, Length of Hood, Temperature of Hot Source and Temperature of Ambient Air.

EQUATION BLOCK 5-021

1. $W_h^{hh} = W_{hs}^{hh} + 0.3$
2. $L_h^{hh} = L_{hs}^{hh} + 0.3$
3. $\Delta t = T_h^{hh} - T_a$
4. $Q_d^{hh} = (L_h^{hh}/0.3) \times 6.2 \times (W_h^{hh}/0.3)^{4/3} \times (\Delta t \times 1.8 + 32)^{5/12} \times (0.3)^3/60$

UNITS

W_h^{hh}, m; L_h^{hh}, m; Δt, ^0c, Q_d^{hh}, m^3/s;

v) Slot Hood for Open Surface Tanks

1. Input: Width of Tank, W^{hh}; Length of Tank, L^{hh}.
2. Compute Slot Width and Design Exhaust Rate. Use Equation Block 5-022.
3. Display Width of Tank, Length of Tank, Slot Width and Design Exhaust Rate.

EQUATION BLOCK 5-022

1. $W_s^{hh} = 5.15969 \times (W^{hh})^{1.11584}$	Slots along Both Long Sides
$= 5.15969 \times (2 \times W^{hh})^{1.11584}$	Slots along One Long Side
2. $Q_d^{hh} = 1.06656 \times (W^{hh})^{1.14481} \times L^{hh}$	Slots along both Long Sides
$= 1.06656 \times 2 \times (W^{hh})^{1.14481} \times L^{hh}$	Slots along one Long Side

UNITS

Q_d^{hh}, m^3/s; W^{hh}, m; L^{hh}, m; W_s^{hh}, m;

5.1.2 Design of Duct

Ducts are used in LEV to carry the contaminant intercepted from hoods to stack or the air control equipment, whatever the case may be. In designing a system of ductwork with multiple branches, the resistance of each branch must be adjusted so that the static pressure balance will give the desired volume in each branch. To accomplish this result two methods are generally used – (i) The Balance Duct or Static Pressure Balance Method, in which duct sizes are chosen so that the static pressure balance at each junction will achieve the desired air volume in each branch duct, and (ii) The Blast Gate Adjustment Method, in which calculation begins at the branch of greatest resistance. The other branches are merely sized to give the minimum required velocity at the desired volume.

DESIGN ALGORITHM OF DUCT

1. Ask if Duct Design is to be Done by Balanced Duct Method or by Blast Gate Adjustment Method and Read the Response.
2. If Ducts to be Designed for Hoods Stored in Hood Design Output File Then Establish Correspondence Between Hood Numeric Labels and Branch Pipe Numeric Labels. Use Equation Block 5-023.
3. Establish Flow Rates Through Various Branch Pipes. Use Equation Block 5-024.

4. Else Prompt to Enter Total Number of Pipes.
5. Prompt to Enter Details of All Pipes One by One as and When Asked.
6. Prompt 'Pipe Number i'
7. Prompt to Enter Numeric Labels of Pipes.
8. Prompt to Enter if it is a 'Branch Pipe' or 'Main Pipe'.
9. If 'Main' ---- Establish Flow Rate Through the Pipe. Use Equation Block 5-025.
10. Compute Diameter and Actual Velocity Through the Pipe. Use Equation Block 5-026.
11. Compute Velocity Pressure for the Flow. Use Equation Block 5-026.
12. If 'Branch' --- Compute Hood Entry Losses. Use Equation Block 5-027.
13. If Elbow/Elbows Present ---- Compute Equivalent Straight Length. Use Equation Block 5-028.
14. If 'Branch' --- If Branch Entry Present --- Compute Equivalent Straight Length. Use Equation Block 5-029.
15. Compute Total Length as Total Length = Actual Length + Elbow Equivalent Length + Branch Equivalent Length.
16. Compute Friction Loss. Use Equation Block 5-030.
17. If 'Branch' --- Compute Static Pressure in Pipe at Pipe's Junction with Main Pipe and Compare Above Calculated Static Pressure with Static Pressure value at the Junction. Use Equation Block 5-031.
18. If 'Main' ---

    If not Last Pipe --- Compute Static Pressure at Pipe's Junction with Succeeding Main Pipe as Static Pressure = Static Pressure at Previous Junction + Friction Loss

    Else, Add Resistance Offered by Air Pollution Control Unit Present Between Second Last Pipe and Last Pipe to Static Pressure at the End of Second Last Pipe
19. I = i + 1. If i ≠ Total Number of Pipes go to 5.
20. Merge the Files of 'Branch Pipes' and 'Main Pipes' Flow Rates and the Files of 'Branch Pipes' and 'Main Pipes' Static Pressure.

UNITS

P_{sp}^d, cm of Water; H_f^d, cm of Water; P_{vp}^d, cm of water; E_{lh}^d, cm of Water; L^d, m; L_{he}^d, m; L_{ee}^d, m; d_p^d, m; Q_g, m^3/s; v_d^d, m/s;

EQUATION BLOCK 5-023

1. Display the Contents of Hood Design Output File.
2. Display the Hood Numeric Label.
3. Prompt to Enter Numeric Label of branch Pipe Originating from the Above Hood.
4. Store the Correspondence Between Hood and Duct Numeric Labels.

EQUATION BLOCK 5-024

1. If Accessing Duct Design After Hood design then Display the Choice
   1. Duct Design for Hoods Stored in Hood Design Output.
   2. Duct Design for Some Other Hood System.
2. If Choice = 1, then
   a) Read the Information Stored in Equation Block 5-023.
   b) Ask if There are any More Branch Pipes Other than those Originating from Hoods Stored in Hood Design Output File. If 'Yes' then Read the Flow Rates for Such Remaining Pipes.
3. If Choice = 2 or if Duct Design is Accessed Directly from Main Menu Without Doing Duct design --- Read Flow Rates for All Branch Pipes.

EQUATION BLOCK 5-025

1. Display Numeric Label of Main Pipe Under Consideration.
2. a) In Case of First Main Pipe Encountered Ask to Enter Numeric Labels of Branch Pipes Present at the Beginning of the Main Pipe.
   b) In Case of Second Main Pipe and Onwards Ask if Branch Pipes are Present at Beginning of the Main Pipe. If 'Yes' then Ask to Enter Numeric Labels of Such Branch Pipes.
3. In Case of Second Pipe and Onwards, Ask if Main Pipes are Present at Beginning of the Main Pipe. If 'Yes' then Ask to Enter Numeric Labels of Such main Pipes.
4. Compute Flow Rate of Main Pipe Under Consideration by Adding Flow Rates of All Pipes Whose Numeric Labels have been Entered in (2) and (3) Above.

EQUATION BLOCK 5-026

1. Display Recommended Minimum Duct Velocities.
2. Prompt to Enter Required Minimum Duct velocity.
3. Display the Exact Diameter Required for the Velocity Entered in (2).
4. Prompt to Enter Nearest Diameter Pipe Available Slightly Lesser than the Diameter Displayed.
5. Display the Actual Velocity in the Pipe for the Diameter Displayed in (4).

EQUATION BLOCK 5-027

Display Various Types of Hood Enteries.

1. Plain Duct End Hood Entry	Coefficient = 0.9
2. Flanged Duct End Hood Entry	Coefficient = 0.5
3. Trap or Settling Chamber Hood Entry	Coefficient = 1.5
4. Standard Grinder Hood Entry	Coefficient = 0.65
5. Sharp Edge Orfice Hood Entry	Coefficient = 1.8
6. Flared Hood Entry	Coefficient = 0.15
7. Orfice Plus Flanged Duct Hood Entry	Coefficient = 2.3
8. Direct Branch Booth Hood Entry	Coefficient = 0.5
9. Bell Mouth Hood Entry	Coefficient = 0.025

10. Tapered Hood Entry

For Round Tapering Section, Coefficient = 0.318233 – 0.0155582 x Taper Angle + 0.000336506 x (Taper Angle)^2 – 3.28324 x 10^{-6} x (Taper Angle)^3 + 1.67535 x 10^{-8} x (Taper Angle)^4 —3.36642 x 10^{-11} x (Taper Angle)^5.

For Rectangular Tapering Section, Coefficient = 0.410292 – 0.0142047 x Taper Angle + 0.000243574 x (Taper Angle)^2 – 1.41819 x 10^{-6} x (Taper Angle)^3 + 2.818869 x 10^{-9} x (Taper Angle)^4

Hood Entry Loss = Coefficient x Velocity Pressure

EQUATION BLOCK 5-028

1. Ask if Elbows are Present in Pipe Under Consideration
2. If 'Yes' Ask Total Number of Elbows in Pipe Under Consideration.
3. For All Elbows in the Pipe i,

   a) Display the Choice

   1- 90^0 Elbow

   2- 60^0 Elbow

   3- 45^0 Elbow

   b) Prompt to Enter the Choice.

   c) Further Display the Choice

   1- Elbow Throat Radius/Pipe Diameter = 1.0

   2- Elbow Throat Radius/Pipe Diameter = 1.5

   3- Elbow Throat Radius/Pipe Diameter = 2.0

   d) Prompt to Enter the Choice.

4. Compute the Equivalent Length

   For Combination 1-1: Equivalent Length = 1.27869 x (Pipe Diameter)$^{1.19675}$

   1-2: Equivalent Length = 0.938617 x (Pipe Diameter)$^{1.17455}$

   1-3: Equivalent Length = 0.742575 x (Pipe Diameter)$^{1.18652}$

   2-1: Equivalent Length = -1.82801 + 1.53051 x Pipe Diameter + 0.0212741 x (Pipe Diameter)^2 – 0.000272925 x (Pipe Diameter)^3

   2-2: Equivalent Length = -0.938195 + 1.00825 x Pipe Diameter + 0.0157379 x (Pipe Diameter)^2 – 0.000200454 x (Pipe Diameter)^3.

   2.3: Equivalent Length = -1.23758 + 0.896278 x Pipe Diameter + 0.0103895 x (Pipe Diameter)^2 – 0.0000135909 x (Pipe Diameter)^3.

   3-1: Equivalent Length = 0.678405 x (Pipe Diameter)$^{1.1776}$

   3-2: Equivalent Length = -0.0320306 + 0.590966 x Pipe Diameter + 0.0127155 x (Pipe Diameter)^2 – 0.000125876 x (Pipe Diameter)^3

   3-3: Equivalent Length = -0.253637 + 0.499118 x Pipe Diameter + 0.0101539 x (Pipe Diameter)^2 – 0.000102026 x (Pipe Diameter)^3

EQUATION BLOCK 5-029

1. Ask if Branch Entry Present in Pipe Under Consideration.
2. If 'Yes' Display the Choice

   1- 45^0 Branch Entry

   2- 30^0 Branch Entry

   3- 15^0 Branch Entry
3. Compute Straight Length of Pipe Equivalent to the Branch Entry.

   In Case of 45^0 Entry, Equivalent Length = -0.537534 + 1.13683 x Pipe Diameter + 0.0365214 x $(\text{Pipe Diameter})^2$ + 0.000573688 x $(\text{Pipe Diameter})^3$

   In Case of 30^0 Entry, Equivalent Length = -0.113733 + 0.720469 x Pipe Diameter + 0.0208043 x $(\text{Pipe Diameter})^2$ – 0.00029353 x $(\text{Pipe Diameter})^3$

   In Case of 15^0 Entry, Equivalent Length = -0.00270415 + 0.268724 x Pipe Diameter + 0.0179015 x $(\text{Pipe Diameter})^2$ – 0.00029837 x $(\text{Pipe Diameter})^3$

EQUATION BLOCK 5-030

1. $h_F^* = 54.6525 \times 10^6 \times (\text{Pipe Diameter})^{-4.91933} \times (\text{Flow Rate of Pipe})^{1.97871}$
2. Friction Loss = h_F^* x Total Pipe Length/30.5

EQUATION BLOCK 5-031

1. From the Stored Values Read Static Pressure at the End of Branch Pipe i and also Static Pressure at the Junction at Which Branch Pipe Meets Some Main Pipe.
2. If Static Pressure in Branch Pipe i (SPB_i) < Static Pressure at Junction(SPJ) then

   If the Design is to be Done by Balanced Duct Method then

   1. Compute Difference Between SPB_i and SPJ.
   2. If Difference < 5% then Design of Pipe is O.K.
   3. If Difference is Greater than 5% but Less than 20% then

   a) Put SPB_i = SPJ

   b) New Flow Rate = Present Flow Rate x $(SPJ/SPB_i)^{1/2}$

   c) New Velocity through Pipe i = [New Flow Rate x 4/(π x $(\text{Diameter of Pipe})^2$)]

   d) Compute Velocity Pressure for the Flow as Explained Earlier.

Please move to next page for rest of the Algorithm

3. e) Compute Hood Entry loss as Explained Earlier.

f) If Pipe 'i' is Connected to Some Hood Stored in Hood Design Output then Tell "Exhaust Rate Required through Hood has been Changed to New Exhaust Rate"

Else, If Pipe 'i' is not Connected to Any Such Hood then Tell "Flow Rate Required through Pipe 'i' has been Changed to New Flow Rate.

4. If Difference is Greater than 20%

a) Tell that Diameter of Pipe 'i' has to be Reduced.

b) Read the New Diameter(Slightly Less than Present Diameter).

c) New Velocity = [Flow Rate x 4/(π x (New Diameter of Pipe)^2)]

d) Compute Velocity Pressure for the Flow as Explained Earlier.

e) Compute Hood Entry Loss for the Flow as Explained Earlier.

f) Compute Equivalent Straight Pipe Length Equivalent to Elbows in Pipe as Explained Earlier.

g) Compute Straight Pipe Length Equivalent to Branch Entry(if Present) in Pipe 'i' as Explained Earlier.

h) Compute Total Length as Explained Earlier.

i) Compute Friction Losses as Explained Earlier.

j) Compute New SPBi as Explained Earlier.

k) Go to (2).

5. If SPB_i < SPJ then

1. Compute the Difference Between SPB_i and SPJ.

2. If Difference < 5% then Design of Pipe is O.K.

3. If Difference > 5% then Tell "Going to Beginning of Duct Design. Please Start from Branch of Greater Resistance or Diameter Reduced too Much".

5.1.3 Design of Fan

Fans are used to move air from one point to another. In the control of air pollution the fan, blower or exhauster imparts movement to air mass and conveys the air contaminant from the source of generation to a control device.

1. Input: Fan Static Pressure, P_{sf}^f; Volume of Air Flow, Q_g^f.
2. If Fan Static Pressure is Greater than 2.54 cm but Lesser than 22.86 cm of Water, Compute RPM Required for Fan, BHP Required for Fan, Outlet Velocity and Outlet Velocity Pressure. Use Equation Block 5-032. Else Tell that "Available Data Limits Fan Design by This Package to Fan Static Pressure Between 2.54 cm to 22.86 cm of Water Whereas the Present Fan Static Pressure Lies Outside This Range".
3. Display Fan Static Pressure, Volume of Air Flow, RPM and BHP of Fan, Outlet Velocity and Outlet Velocity Pressure.

EQUATION BLOCK 5-032

$Q^* = 2118.88 \times Q_g^f$

$P_{sf}^f = 2.54$ cm of Water.

$\omega^f = 404.29 - 0.010204 \times Q^* + 7.17584 \times 10^{-6} \times Q^{*2} + 1.51389 \times 10^{-9} \times Q^{*3} - 3.43421 \times 10^{-13} \times Q^{*4} + 1.92892 \times 10^{-17} \times Q^{*5}$

$bhp^f = 0.632346 - 0.000352015 \times Q^* + 1.4548 \times 10^{-7} \times Q^{*2} + 1.53881 \times 10^{-12} \times Q^{*3} - 2.01628 \times 10^{-15} \times Q^{*4} + 1.64214 \times 10^{-19} \times Q^{*5}$

$P_{sf}^f = 5.08$ cm of Water

$\omega^f = 815.184 - 0.268419 \times Q^* + 0.00011269 \times Q^{*2} + 2.0414 \times 10^{-8} \times Q^{*3} - 1.83663 \times 10^{-12} \times Q^{*4} - 6.37728 \times 10^{-17} \times Q^{*5}$

$bhp^f = 0.620223 - 0.000119515 \times Q^* + 2.1928 \times 10^{-7} \times Q^{*2} - 3.76219 \times 10^{-11} \times Q^{*3} + 4.09368 \times 10^{-15} \times Q^{*4} - 1.33099 \times 10^{-19} \times Q^{*5}$

$P_{sf}^f = 7.62$ cm of Water

$\omega^f = 27.9305 + 0.744212 \times Q^* - 0.00030529 \times Q^{*2} + 6.02864 \times 10^{-8} \times Q^{*3} - 5.55024 \times 10^{-12} \times Q^{*4} + 1.94111 \times 10^{-16} \times Q^{*5}$

$bhp^f = 4.17803 - 0.003314 \times Q^* + 1.5169 \times 10^{-6} \times Q^{*2} - 2.74518 \times 10^{-10} \times Q^{*3} + 2.47021 \times 10^{-14} \times Q^{*4} - 8.18488 \times 10^{-19} \times Q^{*5}$

$P_{sf}^f = 10.16$ cm of Water

$\omega^f = 867.613 - 0.0355223 \times Q^* + 1.0556 \times 10^{-5} \times Q^{*2} - 6.3907 \times 10^{-10} \times Q^{*3} + 2.45887 \times 10^{-14} \times Q^{*4} - 4.27793 \times 10^{-19} \times Q^{*5}$

$bhp^f = -0.326322 + 0.00179482 \times Q^* - 4.24837 \times 10^{-7} \times Q^{*2} + 8.48618 \times 10^{-11} \times Q^{*3} - 6.35201 \times 10^{-15} \times Q^{*4} + 1.86718 \times 10^{-19} \times Q^{*5}$

$P_{sf}^f = 12.7$ cm of Water

$\omega^f = 972.071 - 0.0496768 \times Q^* + 1.66908 \times 10^{-5} \times Q^{*2} - 1.76711 \times 10^{-9} \times Q^{*3} + 1.09376 \times 10^{-13} \times Q^{*4} - 2.67908 \times 10^{-18} \times Q^{*5}$

$bhp^f = 16.1191 - 0.0105773 \times Q^* + 3.3111 \times 10^{-6} \times Q^{*2} - 4.43715 \times 10^{-10} \times Q^{*3} + 2.90945 \times 10^{-14} \times Q^{*4} - 7.17434 \times 10^{-19} \times Q^{*5}$

$P_{sf}^f = 15.24$ cm of Water

$\omega^f = 1210.57 - 0.144984 \times Q^* + 3.8024 \times 10^{-5} \times Q^{*2} - 4.12636 \times 10^{-9} \times Q^{*3} + 2.36158 \times 10^{-13} \times Q^{*4} - 5.37532 \times 10^{-18} \times Q^{*5}$

$bhp^f = -71.8968 + 0.0551111 \times Q^* - 1.52797 \times 10^{-5} \times Q^{*2} + 2.0781 \times 10^{-9} \times Q^{*3} - 1.3455 \times 10^{-13} \times Q^{*4} + 3.35732 \times 10^{-18} \times Q^{*5}$

$P_{sf}^f = 17.78$ cm of Water

$\omega^f = 1326.52 - 0.151636 \times Q^* + 3.85359 \times 10^{-5} \times Q^{*2} - 4.34377 \times 10^{-9} \times Q^{*3} + 2.62494 \times 10^{-13} \times Q^{*4} - 6.29424 \times 10^{-18} \times Q^{*5}$

$bhp^f = 22.8382 - 0.0129922 \times Q^* + 3.74724 \times 10^{-6} \times Q^{*2} - 4.71347 \times 10^{-10} \times Q^{*3} + 2.95905 \times 10^{-14} \times Q^{*4} - 7.0916 \times 10^{-19} \times Q^{*5}$

$P_{sf}^f = 20.32$ cm of Water

$\omega^f = 965.144 + 0.145428 \times Q^* - 4.04604 \times 10^{-5} \times Q^{*2} + 5.84971 \times 10^{-9} \times Q^{*3} - 1.08718 \times 10^{-12} \times Q^{*4} + 2.40427 \times 10^{-17} \times Q^{*5}$

$bhp^f = 59.1834 - 0.0334953 \times Q^* + 8.59308 \times 10^{-6} \times Q^{*2} - 1.02079 \times 10^{-9} \times Q^{*3} + 5.99306 \times 10^{-14} \times Q^{*4} - 1.36446 \times 10^{-18} \times Q^{*5}$

$P_{sf}^f = 22.86$ cm of Water

$\omega^f = 242.24 + 0.638687 \times Q^* - 0.000157611 \times Q^{*2} + 1.90236 \times 10^{-8} \times Q^{*3} - 1.08718 \times 10^{-12} \times Q^{*4} + 2.40427 \times 10^{-17} \times Q^{*5}$

$bhp^f = -35.0392 + 0.0253441 \times Q^* - 5.76504 \times 10^{-6} \times Q^{*2} + 6.82271 \times 10^{-10} \times Q^{*3} - 3.82442 \times 10^{-14} \times Q^{*4} + 8.43523 \times 10^{-19} \times Q^{*5}$

$v_o^f = 1.92216 \times 10\text{-}7 \times Q^{*1.00524}$

$P_{vp}^f = 23.011103 \times 10\text{-}9 \times Q^{*2.00897}$

UNITS

ω^f, Rotation per Minute; bhp^f, Brake Horse Power; Q_g^f, m^3/s; v_o^f, m/s; P_{sf}^f, cm of Water; P_{vp}^f, cm of Water

5.2 Emission Control Equipment

Emission control equipment include (i) equipment to remove the suspended particulate matter in the emission, and (ii) equipment to remove the gaseous contamination.

5.2.1 Particulate Removal Equipment

(i) Design of Settling Chambers

1. Input: Gas Flow Rate, Q_g; Particle Diameter, d_p^{sp}; Specific Gravity, G_s; Kinematic Viscosity, υ_g; Number of Trays, N_{tr}^{sp}; Expected Efficiency, η; Length to Width Ratio of Settling Chambers, R_{lw}^{sp}.
2. Compute Chamber Parameters(Length, Width and Height) and Reynolds Number. Use Equation Block 5-033.
3. If Reynolds Number > 2300

   "Do You Want to Add More Trays for Flow to be Laminar"

   If "Yes" go to (5) Else (4).
4. Compute Total Number of Trays Required, Length, Width and Depth. Use Equation Block 5-034.
5. Compute Total Number of Trays Required, Length, Width and Depth for Turbulent Flow. Use Equation Block 5-035.
6. Display Gas Flow Rate, Efficiency of Removal, Number of Trays, Length, Width, Spacing Between Trays, Total Height of Chamber.

DEFAULT VALUES

$d_p^{sp} = 50 \times 10^{-6}$ m, $G_s = 2.0$, $\upsilon_g = 1.5 \times 10^{-5}$ m^2/s, $N_{tr}^{sp} = 1.0$, $\eta = 0.99$, $R_{lw}^{sp} = 1.0$.

RANGE

$d_p^{sp} = 50\text{-}100 \times 10^{-6}$ m, $N_{tr}^{sp} = 1.0\text{-}20.0$, $\eta = 0.99$, $R_{lw}^{sp} = 1.0\text{-}4.0$.

EQUATION BLOCK 5-033

1. $v_{st}^{sp} = [(g \times (d_p^{sp})^2 \times G_s/18 \times \upsilon_g]$
2. $K_s^{sp} = \eta \times Q_g/v_{st}^{sp}$
3. $y_{tr}^{sp} = [(K_s^{sp})^{1/3}/N_{tr}^{sp}] \times 0.5$
4. $H_t^{sp} = N_{tr}^{sp} \times y_{tr}^{sp}$

5. $W^{sp} = [K_s^{sp}/N_{tr}^{sp} \times R_{lw}^{sp}]^{1/2}$

6. $L^{sp} = R_{lw}^{sp} \times W^{sp}$

7. $R_e = [2 \times Q_g/\upsilon_g \times (N_{tr}^{sp} \times W^{sp} + H_t^{sp})]$

UNITS

v_{st}^{sp}, m/s; y_{tr}^{sp}, m; H_t^{sp}, m; W^{sp}, m; L^{sp}, m;

EQUATION BLOCK 5-034

1. $N_{tr}^{sp} = [(2 \times Q_g)/(\upsilon_g \times W^{sp} \times 2300)]$
2. $W^{sp} = [K_s^{sp}/(N_{tr}^{sp} \times R_{lw}^{sp})]^{1/2}$
3. $L^{sp} = R_{lw}^{sp} \times W^{sp}$
4. $y_{tr}^{sp} = H_t^{sp} / N_{tr}^{sp}$

UNITS

W^{sp}, m; L^{sp}, m; y_{tr}^{sp}, m;

EQUATION BLOCK 5-035

1. $K_s^{sp} = (- Q_g/v_{st}^{sp}) \times \log_e(1 - \eta)$
2. $y_{tr}^{sp} = [(K_s^{sp})^{1/3}/N_{tr}^{sp}]^{3/2} \times 0.5$
3. $W^{sp} = [K_s^{sp}/(N_{tr}^{sp} \times R_{lw}^{sp})]^{1/2}$
4. $L^{sp} = R_{lw}^{sp} \times W^{sp}$
5. $H_t^{sp} = N_{tr}^{sp} \times y_{tr}^{sp}$

UNITS

y_{tr}^{sp}, m; W_{tr}^{sp}, m; L^{sp}, m; H_t^{sp}, m;

ii) Design of Cyclone Chambers

1. Input: Gas Flow Rate, Q_g; Gas Viscosity, υ_g; Width of Gas Inlet, W_{gi}^{cp}; Inlet Velocity, v_{gi}^{cp}; Particle Density, G_s; Gas Density, ρ_g; Diameter of Cyclone, d_{cy}^{cp}; Efficiency of Motor and Drive, η_m^{cp}.
2. Compute Number of Turns, Cut Size Particle Diameter. Use Equation Block 5-036.

3. Enter the Type of Cyclone Chamber.

   "Do You Want to Work with Default Values"

   If "yes" go to (4) Else (5).

4. Compute the Dimension of Cyclone Chamber. Use Equation Block 5-037. Go to (7).
5. Input: Ratio of Length of Cylinder to Diameter of Cyclone, R_{lcd}^{cp}; Ratio of Length of Cone to Diameter of Cyclone, R_{lccd}^{cp}; Ratio of Height of Entrance to Diameter of Cyclone, R_{hd}^{cp}; Ratio of Diameter of Exit Cylinder to Diameter of Cyclone, R_{ed}^{cp} Ratio of Diameter of Dust Exit to Diameter of Cyclone, R_{ddc}^{cp}.
6. Compute the Dimension of Cyclone Chamber. Use Equation Block 5-037.
7. Input: Particle Size, Weight Fraction.
8. Compute Efficiency of Cyclone Chamber, Head Loss and Break Horse Power Required. Use Equation Block 5-038.
9. Display Gas Flow Rate, Dimensions of Cyclone, Number of Turns, Cut Size Particle Diameter, Efficiency and Break Horse Power Required.

DEFAULT VALUES

$\mu_g = 1.84 \times 10^{-5}$ kg/m-s, $W_{gi}^{cp} = 0.3$ m, $v_{gi}^{cp} = 15$ m/s, $d_{cy}^{cp} = 1.2$ m, $\eta_m^{cp} = 0.75$.

RANGE

$W_{gi}^{cp} = 0.25\text{-}0.40$ m, $v_{gi}^{cp} = 12\text{-}18$ m/s, $d_{cy}^{cp} = 1.0\text{-}1.5$ m, $\eta_m^{cp} = 0.75\text{-}0.90$.

EQUATION BLOCK 5-036

1. Find out the value of N_{tu}^{cp} from the expression $v_{gi}^{cp} = 76.59375 - 40.3203 \times N_{tu}^{cp} + 8.99854 \times (N_{tu}^{cp})^2$
2. $d_{cs}^{cp} = [(9 \times \mu_g \times Wgicp)/(2\pi \times N_{tu}^{cp} \times v_{gi}^{cp} \times (\rho_s - \rho_g))]$

UNITS

d_{cs}^{cp}, m;

EQUATION BLOCK 5-037

1. $L_{cy}^{cp} = R_{lcd}^{cp} \times d_{cy}^{cp}$
2. $L_{cn}^{cp} = R_{lccd}^{cp} \times d_{cy}^{cp}$
3. $H_e^{cp} = R_{hd}^{cp} \times d_{cy}^{cp}$
4. $d_{ecy}^{cp} = R_{ed}^{cp} \times d_{cy}^{cp}$
5. $d_{de}^{cp} = R_{dd}^{cp} \times d_{cy}^{cp}$

6. $H_{ge}^{cp} = R_{gd}^{cp} \times d_{cy}^{cp}$
7. $H^{cp} = L_{cn}^{cp} + L_{cy}^{cp}$

UNITS

L_{cy}^{cp}, m; L_{cn}^{cp}, m; H_{e}^{cp}, m; d_{ecy}^{cp}, m; d_{de}^{cp}, m; H_{ge}^{cp}, m; H^{cp}, m;

EQUATION BLOCK 5-038

1. $d_{pi}^{cp} = d_{pl}^{cp} + d_{pm}^{cp}/2$
2. $\eta_{i}^{cp} = 107.8513 - 68.86072/d_{pi}^{cp} + 12.44186/(d_{pi}^{cp})^2$
3. $\eta_{o}^{cp} = \Sigma\eta_{i}^{cp}$
4. $v_{hh}^{cp} = 0.003 \times \rho_g \times (v_{gi}^{cp})^2$
5. $H_{l}^{cp} = 13 \times [(W_{gi}^{cp} \times H_{e}^{cp})/(d_{ecy}^{cp})^2] \times v_{hh}^{cp}$
6. $P_{i}^{cp} = Q_g \times v_{hh}^{cp}$
7. $P_{m}^{cp} = P_{i}^{cp}/\eta_{m}^{cp}$.

UNITS

d_{pi}^{cp}, mm; v_{hh}^{cp}, m; H_{l}^{cp}, m; P_{i}^{cp}, KW;

iii) Design of Electrostatic Precipitator

1. Input: Gas Flow Rate, Q_g; Precipitation Rate, R_{pp}^{esp}; Inlet Dust Loading, L_{di}^{esp}, Plate Spacing, y_{pl}^{esp}; Plate Height, H_{pl}^{esp}; Ratio of Length to Height of Plate, R_{lhp}^{esp}; Gas Temperature, T_g^{esp}; Tube Diameter, d_t^{esp}; Length of Tube, L_{tu}^{sp}; Bulk Gas Velocity, v_{bg}^{esp}.
2. Compute Surface Area Required, Number of Bus Sections, Resistivity and Dimension of Electrostatic Precipitator. Use Equation Block 5-039.
3. Display Dimension of the Electrostatic Precipitator(Length, Height, Number of Bus Sections), Resistivity, Gas Flow Rate, Migration Velocity, Removal Efficiency.

DEFAULT VALUES

R_{pp}^{esp}= 0.10 m/s, y_{pl}^{esp} = 0.25 m, H_{pl}^{esp} = 10 m, R_{lhp}^{esp} = 1.0, T_g^{esp} = 60^0 C, d_t^{esp} = 0.3 m, L_{tu}^{esp} = 3.0 m, v_{bg}^{esp} = 1.2 m/s.y_{pl}^{esp} = 0.20-0.30 m, H_{pl}^{esp} = 3.5-15.0 m, R_{lhp}^{esp} = 1.0-2.0, d_t^{esp} = 0.15-0.3o m, L_{tu}^{esp} = 2.0-5.0 m, v_{bg}^{esp} = 0.6-2.4 m/s.

RANGE

R_{pp}^{esp}= 0.03-0.20 m/s, y_{pl}^{esp} = 0.20-0.30 m, H_{pl}^{esp} = 3.5-15.0 m, R_{lhp}^{esp} = 1.0-2.0, d_t^{esp} = 0.15-0.3o m, L_{tu}^{esp} = 2.0-5.0 m, v_{bg}^{esp} = 0.6-2.4 m/s.

EQUATION BLOCK 5-039

1. $\eta^{esp} = [(L_{di}^{esp} - L_{do}^{esp})/L_{di}^{esp}]$
2. $\phi = -\mathrm{loge}(1-\eta^{esp})$

If ESP is Plate Type

3. $A^{esp} = [\phi \text{ x } Q_g^{esp}/R_{pp}^{esp}]$
4. $N_{pl}^{esp} = \mathrm{Int}[Q_g /(v_{bg}^{esp} \text{ x } H^{esp} \text{ x } y_{pl}^{esp})]$
5. $L_{pse}^{esp} = [A^{esp} /(2 \text{ x } N_{pl}^{esp} \text{ x } H^{esp} \text{ x } y_{pl}^{esp})]$
6. $L_o^{esp} = N_{bus}^{esp} \text{ x } L_{pse}^{esp}$
7. $W^{esp} = (1 + N_{pl}^{esp}) \text{ x } y_{pl}^{esp}$
8. $hrt^{esp} = L_o^{esp}/v_{bg}^{esp}$

If the ESP is Cylindrical

9. $A^{esp} = \phi \text{ x } Q_g^{esp}/R_{pp}^{esp}$
10. $N_{cy}^{esp} = [A^{esp}/(\pi \text{ x } d_{cy}^{esp} \text{ x } H_{cy}^{esp})]$
11. $v_{bg}^{esp} = [(Q_g^{esp} \text{ x } 4)/(N_{cy}^{esp} \text{ x } \pi \text{ x } (d_{cy}^{esp})^2)]$
12. $hrt^{esp} = H^{esp}/v_{bg}^{esp}$

UNITS

A^{esp}, m^2; L_{pse}^{esp}, m; L_o^{esp}, m; W^{esp}, m; hrt^{esp}, s; v_{bg}^{esp}, m/s; H^{esp}, m;

5.2.2 Gaseous Pollutant Removal

(i) Packed Bed Tower

1. Input: Gas Flow Rate, Q_g; Gas Density, ρ_g^{ab}; Liquid Density, ρ_l^{ab}; Nominal Packing Size, S_p^{ab}; Liquid Viscosity, μ_l^{ab}; Removal Efficiency, η; Fraction of Pollutant in the Gas Stream, F_v^{ab}; Temperature, T_a; Gas Diffusivity, D_{gg}^{ab}; Packing Constants α, β, γ; Liquid Diffusivity, D_{ll}^{ab}; Pressure Drop Constant m_1; Pressure Drop Constant n; Slope of The Equilibrium Line.

2. Compute Packing Factor, Superficial Mass Gas Velocity and Tower Diameter. Use Equation Block 5-040.
3. Compute Number of Transfer Units, Height of Packed Tower, Tower Pressure Drop. Use Equation Block 5-041.
4. Display Gas Flow Rate, Liquid Flow Rate, Removal Efficiency, Fraction of Pollutant in the Gas Stream, Temperature, Diameter of Packed Bed Tower, Number of Transfer Units, Total Height of Tower and Tower Pressure Drop.

DEFAULT VALUES

$\rho_g^{ab} = 1.185$ kg/m^3, $\rho_l^{ab} = 1000$ kg/m^3, $S_p^{ab} = 1$ in, $\mu_l^{ab} = 9.239 \times 10^{-4}$ kg/m-s, $\mu_g^{ab} = 1.84 \times 10^{-5}$ kg/m-s, $F_v^{ab} = 0.10$, $\eta^{ab} = 0.95$, $T^a = 25^0$ C, $d_g^{ab} = 0.236$ cm^2/s, $\alpha = 7.0$, $\beta = 0.39$, $\gamma = 0.58$(Rasching Ring), $d_l^{ab} = 1.50$, m1 = 32.10, n = 0.00434, m = 0.75.

DEFAULT VALUES

$S_p^{ab} = 1$ in, $\mu_l^{ab} = 9.239 \times 10^{-4}$ kg/m-s, $F_v^{ab} = 0.10$, $\eta^{ab} = 0.95$, $T^a = 25^0$ C, $d_g^{ab} = 0.236$ cm^2/s, $\alpha = 7.0$, $\beta = 0.39$, $\gamma = 0.58$(Rasching Ring), $d_l^{ab} = 1.50$, m1 = 32.10, n = 0.00434, m = 0.75.

EQUATION BLOCK 5-040

1. $G_l = 7956 \times \rho_g^{ab} \times Q_g$
2. $G_{ml} = G_l/M_g$
3. $L_{ml} = G_{ml} \times 0.75/0.70$
4. $L_l = L_{ml} \times M_l$
5. $Q_{go}^{ab} = G_{ml} \times (1 - F_{pg}^{ab} \times \eta^{ab}) \times M_g$
6. $Q_{lo}^{ab} = L_{ml} + (G_{ml} - Q_{go}^{ab})$
7. $K_{top} = (L_l/Q_{go}^{ab}) \times (\rho_g^{ab}/\rho_l^{ab})^{0.5}$
8. $K_{bottom} = (Q_{lo}^{ab}/G_l) \times (\rho_g^{ab}/\rho_l^{ab})^{0.5}$
9. For Maximum Value of K_{top} and K_{bottom} (K = Maximum of K_{top} and K_{bottom})

$$R = [(G^2 \times f_p^{ab} \times (\mu_l^{ab})^{0.2})/(g_c \times \rho_g^{ab} \times \rho_l^{ab})]$$
$$= 0.296051 - 2.63489 \times K + 7.98535 \times K^2 - 7.95508 \times K^3 \quad (0.01<K<0.1)$$
$$= -0.109408 + 2.15748 \times 10^{-2}/K \quad (0.1<K<1.0)$$
$$= 0.5292091 + 1.33021 \times 10^{-2}/K - 5.48671 \times 10^{-6}/K^2 \quad (1.0<K<10)$$

10. $G = [(R \times 32.2 \times \rho_l^{ab} \times \rho_g^{ab})/(f_p^{ab} \times (\mu_l^{ab})^{0.2})]^{0.5}$

$\rho_l^{ab} = \rho_l^{ab} \times (0.3)^3/0.452$

$\rho_g^{ab} = \rho_g^{ab} \times (0.3)^3/0.452$

11. $A_{cs}^{ab} = [L_l^{ab}/(0.60 \times G \times 3600)]$

12. $d^{ab} = 0.30 \times [A_{cs}^{ab} \times 4/\pi]^{0.5}$

UNITS

G_l, lb/h; G_{ml}, lb-moles/h; L_l, lb/h; L_{ml}, lb-moles/h; G, lb/s-ft^2; A_{cs}^{ab}, m^2; d^{ab}, m;

EQUATION BLOCK 5-041

1. $Y_1 = [(F_{pg}^{ab} \times G_{ml}^{ab})/((1 - F_{pg}^{ab}) \times G_{ml}^{ab})]$
2. $X_1 = [(\eta^{ab} \times F_{pg}^{ab} \times G_{ml}^{ab})/L_{ml}]$
3. $Y_2 = [((1 - \eta^{ab}) \times F_{pg}^{ab} \times G_{ml}^{ab})/((1 - F_{pg}^{ab}) \times G_{ml}^{ab})]$
4. $X_2 = 0$
5. $N_{tu}^{ab} = \log_e[((Y_1 - mX_2)/(Y_2 - mX_2)) \times (1 - 1/(L_{ml}/mG_{ml})) \times 1/(L_{ml}/mG_{ml})]/(1 - 1/(L_{ml}/mG_{ml}))$
6. $U_{gt}^{ab} = \alpha \times [(G_l/A_{cs}^{ab})^{\beta}/(L_l/A_{cs}^{ab})^{\gamma}] \times [\mu_g^{ab}/(\rho_g^{ab} \times D_{gg}^{ab})]^{0.5}$
7. $U_{lt}^{ab} = \phi \times [L_l/(A_{cs}^{ab} \times \mu_l^{ab})]^{\eta} \times [\mu_l^{ab}/(\rho_l^{ab} \times D_{ll}^{ab})]^{0.5}$
8. $U_{og}^{ab} = U_{gt}^{ab} + m \times G_{ml} \times U_{lt}^{ab}/L_{ml}$
9. $H^{ab} = N_{tu}^{ab} \times U_{og}^{ab} \times 0.3$
10. $p_{dt}^{ab} = m_1 \times 10^{-8} \times 10^{(n \times L_l/(\rho_g^{ab} \times Acs))} \times (G_l/A_{cs}^{ab}) \times 1/\rho_g^{ab} \times H^{ab}$

UNITS

U_{gt}^{ab}, ft; U_{lt}^{ab}, ft; U_{og}^{ab}, ft; H^{ab}, m; p_{dt}^{ab}, lb/ft^2;

(ii) Design of Tray Towers

1. Input: Gas Flow Rate, Q_g^{ab}; Solvent Flow Rate, Q_l^{ab}; Removal Efficiency, η^{ab}, Fraction of Pollutant in the Gas Stream, F_{pg}^{ab}; Slope of the Equilibrium Line, m; Tray Spacing Constant k, Liquid Density, ρ_l^{ab}, Gas Density, ρ_g^{ab}.
2. Compute Number of Theoretical Plates, Tower Diameter, Height. Use Equation Block 5-042.

3. Display Liquid Flow Rate, Gas Flow Rate, Removal Efficiency, Fraction of Pollutant Gas in the Gas Stream, Tower Diameter, Number of Plates, Tower Height, Size of Bubble Caps, Spacing of Bubble Caps.

DEFAULT VALUES

$\eta^{ab} = 0.95$, $F_{pg}{}^{ab} = 0.1$, $m = 0.75$, $k = 0.17$, $\rho_l{}^{ab} = 1000\ kg/m^3$, $\rho_g{}^{ab} = 1.185\ kg/m^3$.

EQUATION BLOCK 5-042

1. $G_L = [Q_g \times 3600 \times \rho_g{}^{ab}/0.452]$
2. $L_L = [Q_l \times 3600 \times \rho_l{}^{ab}/0.452]$
3. $G_{ML} = G_L/M_g$
4. $L_{ML} = L_L/M_l$
5. $Y_1 = [F_{pg}{}^{ab}/(1 - F_{pg}{}^{ab})]$
6. $X_1 = [\eta^{ab} \times F_{pg}{}^{ab} \times G_{ML}/L_{ML}]$
7. $Y_2 = [((1 - \eta^{ab}) \times F_{pg}{}^{ab})/(1 - F_{pg}{}^{ab})]$
8. $X_2 = 0$
9. $\rho_G = [\rho_g \times (0.3)^3/0.452]$
10. $\rho_L = [\rho_l \times (0.3)^3/0.452]$
11. $v_{slg}{}^{ab} = k \times [(\rho_L - \rho_G)/\rho_G]^{0.5}$
12. $A_{cs}{}^{ab} = Q_g/(v_{slg}{}^{ab} \times 0.3)$
13. $d^{ab} = [4 \times A_{cs}{}^{ab}/\pi]^{1/2}$
14. $X = m \times G_{ML}/L_{ML}$
15. $N_{pl}{}^{ab} = \log_e[(1 - X) \times ((Y_1 - mX_2)/(Y_2 - mX_2)) \times X]/\log_e X$
16. $H^{ab} = N_{pl}{}^{ab} \times 1/0.75 \times y_{tr}{}^{ab} \times 0.3$

Where $y_{tr}{}^{ab}$	$= 12 \times 0.0254$	If $d^{ab} < 2.5$ ft
	$= 18 \times 0.0254$	If $2.5 < d^{ab} < 4.0$ ft
	$= 24 \times 0.0254$	$4.0 < d^{ab} < 24$ ft
	$= 36 \times 0.0254$	$d^{ab} > 24$ ft

17. $S_{bb}{}^{ab} =$

3×2.54	If $d^{ab} < 5.0$ ft
4×2.54	$5.0 < d^{ab} < 16.0$ ft
6×2.54	$d^{ab} > 16.0$ ft

18. $y_{cap}{}^{ab} = 0.2 \times S_{bb}{}^{ab}$

UNITS

$v_{slg}{}^{ab}$ ft/s, L_L, lb/hr; G_L, lb/hr; L_{ML}, lb-moles/hr; G_{ML}, lb-moles/hr; $A_{cs}{}^{ab}$, m^2; d^{ab}, m; H^{ab}, m; $y_{tr}{}^{ab}$, m; $S_{bb}{}^{ab}$, m; $y_{cap}{}^{ab}$, cm;

(iii) Design of Fixed Bed Adsorption Tower

1. Input: Gas Flow Rate, Q_g^{ad}; Temperature, T_a; Removal Efficiency, η; Bulk Density of the Adsorbent Bed, ρ_{ad}^{ad}; Adsorption Capacity of Adsorbent, C_{ad}^{ad}; Concentration of Pollutant Specie, C_p^{ad}; Density of Pollutant, ρ_p^{ad}; Superficial Velocity, v_{sup}^{ad}.
2. Compute Amount of Adsorbent Required, Cross-sectional Area, Diameter and Height of Column. Use Equation Block 5-043.
3. Display Gas Flow Rate, Temperature, Removal Efficiency, Bulk Density of Adsorbent, Adsorption Capacity, Concentration of Pollutant at Inlet, Concentration of Pollutant at Outlet, Superficial Velocity, Amount of Adsorbent Required, Diameter of Column, Height of Column.

DEFAULT VALUES

$\eta = 0.99$, Name of the Adsorbent = Activated Carbon, $\rho_{ad}^{ad} = 600$ kg/m^3, $C_p^{ad} = 2000$ ppm, $C_{ad}^{ad} = 28$ kg Pollutant/100 kg Carbon, $v_{sup}^{ad} = 0.5$ m/s

EQUATION BLOCK 5-043

1. $Q_{ag}^{ad} = Q_g^{ad} \times 3600$
2. $Q_{ap}^{ad} = C_p^{ad} \times Q_{ag}^{ad}$
3. $Q_{mp}^{ad} = Q_{ap}^{ad} \times M_p^{ad} \times 10^{-6}/24.5$
4. $M_{pp}^{ad} = \eta \times Q_{mp}^{ad} \times t_d^{ad}$
5. $R_{ad}^{ad} = M_{pp}^{ad}/C_{ad}^{ad}$
6. $V^{ad} = R_{ad}^{ad}/\rho_{ad}^{ad}$
7. $A_{cs}^{ad} = Q_g^{ad}/v_{sup}^{ad}$
8. $d^{ad} = [A_{cs}^{ad} \times 4/\pi]^{1/2}$
9. $H^{ad} = V/A_{cs}^{ad}$

UNITS

Q_{ag}^{ad}, m^3/h; Q_{mp}^{ad}, kg/h; M_{pp}^{ad}, kg; R_{ad}^{ad}, kg/d; V^{ad}, m^3; A_{cs}^{ad}, m^2; d^{ad}, m; H^{ad}, m;

(iv) Design of Thermal Incinerators

1. Input: Gas Flow Rate, Q_g^i; Inlet Temperature, T_{it}^i; Combustion Temperature, T_{ct}^i; Enthalpy of Pollutant Gas at Inlet Temperature, E_{pi}^i; Enthalpy of Pollutant Gas at

Combustion Temperature, E_{pc}^{i}; Available Heat from Fuel Gas at Combustion Temperature, H_{gc}^{i}; Length to Diameter Ratio, R_{ld}^{i}; Density of Pollutant Gas, ρ_g^{i}; Throat Velocity, v_{th}^{i}; Combustion Chamber Velocity, v_{cch}^{i}.

2. Compute Heat Requirement, Volume of Fuel Gas Required, Length and Diameter of the Combustion Chamber. Use Equation Block 5-044.
3. Display Polluted Gas Flow Rate, Inlet Temperature, Combustion Temperature, Fuel Gas Flow Rate, Diameter of Combustion Chamber, Height of Combustion Chamber, Residence Time.

DEFAULT VALUES

$T_{it}^{i} = 30^0C$, $T_{ct}^{i} = 650^0C$, $R_{ld}^{i} = 2.0$, $\rho_g^{i} = 1.185\ kg/m^3$, $v_{th}^{i} = 6.0\ m/s$, $v_{cch}^{i} = 3.5\ m/s$.

EQUATION BLOCK 5-044

1. $M_{gc}^{i} = Q_g^{i} \times \rho_g^{i}$
2. $H_r^{i} = M_{gc}^{i} \times (E_{pc}^{i} - E_{pi}^{i})$
3. $H_{rl}^{i} = 0.1 \times H_r^{i}$
4. $H_{rt}^{i} = H_{rl}^{i} + H_r^{i}$
5. $Q_{fg}^{i} = H_t^{i}/H_{gc}^{i}$
6. $Q_{fgc}^{i} = [(Q_{fg}^{i} \times 11.45 \times (T_{ct}^{i} + 273))/(T_{it}^{i} + 273)]$
7. $Q_{gc}^{i} = [(Q_g^{i} \times (T_{ct}^{i} + 273))/(T_{it}^{i} + 273)]$
8. $Q_{tg}^{i} = Q_{fgc}^{i} + Q_{gc}^{i}$
9. $A_{th}^{i} = Q_{tg}^{i}/v_{th}^{i}$
10. $A_{cch}^{i} = Q_{tg}^{i}/v_{cch}^{i}$
11. $d_{th}^{i} = [A_{th}^{i} \times 4/\pi]^{1/2}$
12. $d_{cch}^{i} = [A_{cch}^{i} \times 4/\pi]^{1/2}$
13. $L_{cch}^{i} = R_{ld}^{i} \times d_{cch}^{i}$
14. $hrt^{i} = [\pi \times (d_{cch}^{i})^2 \times L_{cch}^{i}/Q_{tg}^{i}]$

UNITS

M_{gc}^{i}, kg/s; H_r^{i}, J/s; H_{rl}^{i}, J/s; H_{rt}^{i}, J/s; Q_{fg}^{i}, m^3/s; Q_{tg}^{i}, m^3/s; A_{cch}^{i}, m^2; d_{cch}^{i}, m; L_{cch}^{i}, m; hrt^{i}, s; A_{th}^{i}, m^2; d_{th}^{i}, m;

6 Design Methodologies – II: Water Treatment

In this chapter, design algorithms of various units designed for safe drinking water supply have been given. It has been tried to refer manuals only for formulating the algorithms. But in absence of manual recommended approach for options quite frequent in use, various text book and journals have been consulted. Fair *et al.* (1968), Weber (1972), Degremont (1973), Yao (1973), Dhabadgaonkar and Bhole (1974), Tikhe (1976), Dhabadgaonkar (1977), Patwardhan (1977), Dhabadgaonkar and Ingle (1977), Hudson (1981), Eshwar and Tare (1981), Culp *et al.* (1986), Bhole *et al.* (1987), Peavy *et al.* (1987) are some of the text books and journals consulted for formulating the design approach for various units.

6.1 Design of Diffused Aeration System

1. Input: Average Flow, Q_a; Ambient Temperature, T_a; Molar Gas Constant, R; Absolute Outlet Pressure at Compressor, P_{oc}^{da}; Hydraulic Retention Time, hrt^{da}; Diameter of Nozzle, d_n^{da}; Spacing of Nozzles, y_n^{da}; Diameter of Pipe, d_{ip}^{da}; Spacing of Pipes, y_p^{da}; Length to Height Ratio, R_{lh}^{da}; Width to Height Ratio, R_{wh}^{da}; Air Required/Flow, A_a^{da}, Power Required/Flow, P_{pf}.
2. Put N^{na}=1.
3. Compute Tank Parameters(Volume, Length, Width and Height). Use Equation Block 6-001.
4. If $W^{da} > 9.0$ m, Put $N^{da} = N^{da}+1$.
5. Compute Diffuser Parameters(Number of Pipes, Actual Pipe Spacing, Nozzles/Pipe, Number of Nozzles and Nozzle Spacing). Use Equation Block 6-002.

6. Compute Compressor Parameters, Air Flow, Air Delivery Pressure and Power Requirement. Use Equation Block 6-003.
7. Display Flow, Tank Parameters, Diffuser Parameters and Compressor Parameters.

DEFAULT VALUES

d_n^{da} = 10 mm, y_n^{da} = 1.0 m, d_{ip}^{da} = 0.1 m, y_p^{da} = 1.0 m, R_{lh}^{da} = 3.0, R_{wh}^{da} = 1.5, hrt^{da} = 20 min, R = 8.314 J/mole-K, A_a^{da} = 0.25 $m^3/m^3/h$, P_{pf}^{da} = 10 $w/m^3/h$

RANGE

d_n^{da} = 6-20 mm, y_n^{da} = 0.8-1.5 m, d_{ip}^{da} = 0.1-0.2 m, y_p^{da} = 0.8-1.5 m, R_{lh}^{da} = 2.0-4.0, R_{wh}^{da} = 1.0-2.0, hrt^{da} = 10-30 min, A_{af}^{da} = 0.06-1.0 $m^3/m^3/h$, P_{pf} = 3 – 13 $w/m^3/h$.

EQUATION BLOCK 6-001

1. $V^{da} = Q_a \times hrt^{da}/(1440 \times N^{da})$
2. $H^{da} = [V^{da}/(R_{lh}^{da} \times R_{wh}^{da})]^{1/3}$
3. $W^{da} = R_{wh}^{da} \times H^{da}$
4. $L^{da} = R_{lh}^{da} \times H^{da}$

UNITS

V^{da}, m^3; L^{da}, m; W^{da}, m; H^{da}, m;

EQUATION BLOCK 6-002

1. $N_p^{da} = Int(W^{da}/y_p^{da})$
2. $y_{ap}^{da} = W^{da}/N_p^{da}$
3. $N_{np}^{da} = Int[(L^{da} - y_{ap}^{da})/y_n^{da}$
4. $y_{an}^{da} = [(L^{da} - y_{ap}^{da})/N_{np}^{da}]$
5. $N_n^{da} = N_p^{da} \times N_{np}^{da}$

UNITS

y_p^{da}, m; y_n^{da}, m; y_{ap}^{da}, m; y_{an}^{da}, m;

EQUATION BLOCK 6-003

1. $A_t^{da} = A_a^{da} \times Q_a$
2. $P_r^{da} = P_{pf}^{da} \times (Q_a^{da}/24) \times 10^{-3}$

UNITS

A_t^{da}, m^3/d; P_o^{da}, P_r^{da}, KW;

6.2 Design of Cascade Aeration System

1. Input: Average Flow, Q_a; Area per Unit Flow,A_{af}^c; Diameter of Inlet Pipe, d_{ip}^c; Height of Structure, H^c; Height of Steps, H_s^c.
2. Compute Area of Cascade, Diameter of Cascade, Number of Steps and the Diameter of Cascade at Various Stages. Use Equation Block 6-004.
3. Display Design Flow, Area per Unit Flow, Diameter of Cascade at Bottom, Diameter of Cascade at Various Steps, Diameter of Inlet Pipe, Number of Steps and Rise of Each Step.

DEFAULT VALUES

$A_{af}^c = 0.03$ m^2/m^3/h, $d_{ip}^c = 0.6$ m, $H^c = 1.2$ m, $H_s^c = 0.3$ m.

RANGE

$A_{af}^c = 0.015$-0.045 m^2/m^3/h, $d_{ip}^c = 0.3$-0.75 m, $H^c = 1.2$-3.0 m, $H_s^c = 0.3$-0.4 m.

EQUATION BLOCK 6-004

1. $A^c = A_{af}^c \text{ x } Q_a/24$
2. $d^c = [4 \text{ x } A^c/\pi]^{1/2}$
3. $N_s^c = \text{Int}(H^c/H_s^c)$
4. $0^c = [(d^c - d_{ip}^c)/(2 \text{ x } H^c)]$
5. $d_{ci}^c = d^c - 2 \text{ x i x } H_s^c/0^c$

UNITS

A^c, m^2; d^c, m;

6.3 Design of Spray Type Aerators

1. Input: Average Flow, Q_a; Coefficient of Discharge, cd; Head at Nozzle, H_n^{sa}; Diameter of Nozzle, d_n^{sa}; Coefficient of Velocity, c_v; Wind Velocity, v_w^{sa}; Spacing of Pipes, y_p^{sa}; Area/Flow, A_{af}^{sa}; Angle from Horizontal, θ^{sa}.
2. Compute Number of Nozzles and their Distribution, Width and Length of Aeration Chamber. Use Equation Block 6-005.
3. Display Design Flow, Pressure Head at Nozzle, Number of Nozzles, Diameter of Nozzle, Minimum Spacing between Pipes, Length and Width of Chamber, Spacing of Nozzles along Length and Width.

DEFAULT VALUES

H_n^{sa} = 7 m, d_n^{sa} = 20 mm, cd = 0.61, c_v = 0.9, v_w^{sa} = 8 km/h, A_{af}^{sa} = 0.06 $m^2/m^3/h$, θ^{sa} = 88^0.

RANGE

H_n^{sa} = 2-9 m, d_n^{sa} = 10-40 mm, v_w^{sa} = 8-12 km/h, A_{af}^{sa} = 0.03-0.09 $m^2/m^3/h$, θ^{sa} = 85-88^0.

EQUATION BLOCK 6-005

1. $v_n^{sa} = c_v \times [2 \times g \times H_n^{sa}]^{1/2}$
2. $Q_n^{sa} = cd \times \pi \times (d_n^{sa}/1000)^2 \times c_v \times [2 \times g \times H_n^{sa}]^{1/2}/4$
3. $t_e^{sa} = 2 \times c_v \times [2 \times H_n^{sa}/g]^{1/2} \times \sin\theta^{sa}$
4. $N_n^{sa} = [Q_a/(86400 \times Q_n^{sa})]$
5. $R_s^{sa} = v_n^{sa} \times \cos\theta^{sa} \times t_e^{sa}$
6. $D_w^{sa} = cd \times v_w^{sa} \times t_e^{sa} \times 1000/3600$
7. $y_{mp}^{sa} = R_s^{sa} + D_w^{sa}$
8. $A^{sa} = [Q_a/(A_{af}^{sa} \times 24)]$
9. $W_{ch}^{sa} = 2 \times y_{mp}^{sa}$
10. $L_{ch}^{sa} = A^{sa}/W_{ch}^{sa}$

    If $L_{ch}^{sa} < 2 \times y_{mp}^{sa}$ $\qquad$ $L_{ch}^{sa} = 2 \times y_{mp}^{sa}$
11. $N_{nl}^{sa} = [N_n^{sa}/2(L_{ch}^{sa} + W_{ch}^{sa})]$
12. $N_{nw}^{sa} = \mathrm{Int}(W_{ch}^{sa} \times N_{nl}^{sa})$
13. $N_{ln}^{sa} = \mathrm{Int}(L_{ch}^{sa} \times N_{nl}^{sa})$
14. $y_{nw}^{sa} = W_{ch}^{sa}/N_{nw}^{sa}$
15. $y_{nl}^{sa} = L_{ch}^{sa}/N_{ln}^{sa}$

UNITS

v_n^{sa}, m/s; t_e^{sa}, s; R_s^{sa}, m; D_w^{sa}, m; A^{sa}, m^2; W_{ch}^{sa}, m; L_{ch}^{sa}, m; y_{nw}^{sa}, m; y_{nl}^{sa}, m, Q_n^{sa}, m^3/sec

6.4 Design of Tube Settlers

1. Input: Average Flow, Q_a; Shape Factor, S_f^{ts} Slant Length of Tube, L_{tu}^{ts}; Angle of Inclination, θ^{ts}; Loss of Water in Desludging, l_{ws}^{ts}; Diameter of Tube, d_t^{ts}; Side of Tube, S_t^{ts}; Thickness of Tube, T_t^{ts}; Surface Overflow Rate, sor.
2. Compute Flow Velocity Through Tubes, Tube Entrance Area, Number of Tubes, Length of Tube Module, Width and Height of Tube Module. Use Equation Block 6-006.
3. Display Flow, Shape Factor, Shape of Tube Settler, Angle of Inclination, Side or Diameter of Each Tube, Thickness of Tubes, Number of Tubes, Length, Width and Depth of Tube Module.

DEFAULT VALUES

S_f^{ts}= 11/8, S_t^{ts} = 50 mm, $\theta^{ts} = 60^0$, l_{ws}^{ts} = 2%, T_t^{ts} = 1.5 mm, L_s^{ts} = 1 m, $\upsilon_l = 1.01 \times 10^{-6}$ m^2/s.

RANGE

S_t^{ts} = 50-100 mm, θ^{ts} = 5-60^0, T_t^{ts} = 1.5-5.0 mm, L_s^{ts} = 1-1.5 m, $\upsilon_l = 1.01 \times 10^{-6}$ m^2/s.

EQUATION BLOCK 6-006

1. $L_{rl}^{ts} = L_s^{ts} \times 1000/S_t^{ts}$ or d_t^{ts}
2. $K = 0.058 \times S_t^{ts}$ or $d_t^{ts}/(\upsilon_l \times 86400)$
3. $v_f^{ts} = [(sor \times (\sin\theta^{ts} + L_{rl}^{ts} \times \cos\theta^{ts}))/(S_f^{ts} + sor \times K \times \cos\theta^{ts})]$
4. $Q_d^{ts} = [(Q_a \times 100)/(100 - l_{ws}^{ts})]$
5. $A^{ts} = Q_d^{ts}/(86400 \times v_f^{ts})$
6. $N^{ts} = A^{ts} \times 10^6/A_t^{ts}$
7. $N_r^{ts} = N^{ts}/N_c^{ts}$
8. $L^{ts} = N_r^{ts} \times (S_t^{ts}$ or $d_t^{ts} + 2 \times T_t^{ts}) \times 10^{-3}$
9. $W_{tm}^{ts} = N_c^{ts} \times (S_t^{ts}$ or $d_t^{ts} + 2 \times T_t^{ts}) \times 10^{-3}$
10. $H^{ts} = L^{ts} \times \sin\theta^{ts}$

UNITS

v_f^{ts}, m/s; Q_d^{ts}, m^3/d; A^{ts}, m^2; L_{tm}^{ts}, m; W_{tm}^{ts}, m; H^{ts}, m;

6.5 Design of Plate Settlers

1. Input: Average Flow, Q_a; Surface Overflow Rate, sor^{ps}; Kinematic Viscosity, υ_l; Shape Factor, S_f^{ps}; Flow Velocity Through Plates, v_f^{ps}; Width of Tank, W^{ps}; Spacing Between Plates, y_{pl}^{ps}; Plate Thickness, T_{pl}^{ps}; Inclination from Horizontal, θ^{ps}; Free Board, F_b^{ps}; Sludge Zone Depth, D_{sz}^{ps}; Flow Distribution Zone, D_{dz}^{ps}; Temperature, T_a.
2. Compute Relative Length of Tubes, Transition Relative Length, Plate Parameters (Length and Number) and Tank Parameters(Length, Width and Depth). Use Equation Block 6-007.
3. Display Design Flow, Length, Width and Depth of Tank, Number of Plates, Length and Width of Plate and Inclination from Horizontal.

DEFAULT VALUES

sor^{ps} = 30 $m^3/m^2/d$, S_f^{ps} = 1.0, v_f^{ps} = 0.005 m/s, W^{ps} = 3.0 m, y_{pl}^{ps} = 0.05 m, T_{pl}^{ps} = 0.005 m, $0^{ps} = 45^0$.

RANGE

sor^{ps} = 30-45 $m^3/m^2/d$, v_f^{ps} = 0.004-0.006 m/s, W^{ps} = 3.0-10.0 m, y_{pl}^{ps} = 0.05-0.10 m, T_{pl}^{ps} = 0.005-0.010 m, $0^{ps} = 5\text{-}60^0$

EQUATION BLOCK 6-007

1. $L_{rl}^{ps} = [(v_f^{ps} \times S_f^{ps} - sor^{ps} \times \sin\theta^{ps})/(sor^{ps} \times \cos\theta^{ps})]$
2. $L_{tr}^{ps} = 0.058 \times v_f^{ps}/\upsilon_l$
3. $L_{pl}^{ps} = 2 \times L_{rl}^{ps} \times y_{pl}^{ps}$ (If $L_{tr}^{ps} >= L_{rl}^{ps}$)
4. $L_{pl}^{ps} = (L_{rl}^{ps} + L_{tr}^{ps}) \times y_{pl}^{ps}$ (If $L_{tr}^{ps} < L_{rl}^{ps}$)
5. $W_{pl}^{ps} = W^{ps}$
6. $A_{pl}^{ps} = Q_a/(86400 \times v_f^{ps})$
7. $N_{pl}^{ps} = A_{pl}^{ps}/(y_{pl}^{ps} \times W^{ps})$
8. $L^{ps} = [N_{pl}^{ps} \times (y_{pl}^{ps} + T_{pl}^{ps})] + L_{pl}^{ps} \times \cos 0^{ps}$
9. $H^{ps} = L_{pl}^{ps} \times \cos\theta^{ps} + F_b^{ps} + D_{sz}^{ps} + D_{dz}^{ps}$

UNITS

L_{pl}^{ps}, m; W_{pl}^{ps}, m; L^{ps}, m; W^{ps}, m; H^{ps}, m; A_{pl}^{ps}, m^2;

6.6 Design of Rectangular Clarifier

1. Input: Average Flow, Q_a; Temperature, T_a; Size of Particles to be Removed, d_p^{rc}; Height of Tank, H^{rc}; Length to Width Ratio, R_{lw}^{rc}; Removal Efficiency, η^{rc}; Specific Gravity of Particles, G_s; Performance Factor, P_f^{rc}; Kinematic Viscosity, υ_l; Weir Loading Rate, R_w^{rc}; Spacing of Notches, y_{nh}^{rc}; Width of Effluent Launder, W_{el}^{rc}.
2. Put $N^{rc} = 1$
3. Compute Tank Parameters(Length, Width & Depth). Use Equation Block 6-008.
4. If Length > 90 m, $N^{rc} = N^{rc}+1$

Enter The Type of Influent Structure –

a) Diffuser Wall with Slots or Perforated Baffles. Go to 5.

b) Influent Channel with Submerged Orfice in the Inside Channel Wall. Go to 6.

c) Influent Channel with Bottom Opening. Go to 7.

d) Overflow Weir Followed by a Baffle. Go to 8.

5a Input: Spacing of Slots, y_s^{rc}; Velocity in Slots, v_s^{rc}.

5b Compute Number of Slots and Diameter or Side of Slot. Use Equation Block 6-009.

6a Input: Width of Influent Channel, W_{ic}^{rc}; Number of Orfices, N_o^{rc}; Dimension of Orfice(Side S_o^{rc} or Diameter d_o^{rc}); In Front Distance of Baffle Wall, x_b^{rc}.

6b Compute Head Loss in the Influent Structure. Use Equation Block 6-010.

7a Input: Width of Influent Channel, W_{ic}^{rc}; Depth of Influent Channel, D_{ic}^{rc}.

7b Compute Number and Side of Openings. Use Equation Block 6-011.

8a Input: Width of Influent Channel, w_{ic}^{rc}; Depth of Influent Channel, D_{ic}^{rc}.

8b Compute Length of Channel and Head Loss Through Influent Structure. Use Equation Block 6-012.

9. Compute Length of Outlet Zone and Effluent Launder Parameters. Use Equation Block 6-013.
10. Display Flow, Number of Tanks, Surface Overflow Rate, Tank Parameters, Inlet Parameters and Outlet Parameters.

DEFAULT VALUES

$d_p^{rc} = 0.8$ mm, $H^{rc} = 3.0$ m, $R_{lw}^{rc} = 4.0$, $\eta = 0.75$, $G_s = 1.002$, $P_f^{rc} = 1/8$, $\upsilon_l = 1.01 \times 10^{-6}$ m^2/s, $R_w^{rc} = 200$ $m^3/d/m$, $y_{nh}^{rc} = 0.2$ m, $W_{el}^{rc} = 0.40$ m.

RANGE

$d_p^{rc} = 0.2\text{-}2.0$ mm, $H^{rc} = 3.0\text{-}4.5$ m, $R_{lw}^{rc} = 3.0\text{-}6.0$, $\eta = 0.75\text{-}0.9$, $P_f^{rc} = 1/8\text{-}1.0$, $R_w^{rc} = 175\text{-}225$ $m^3/d/m$, $y_{nh}^{rc} = 0.2\text{-}0.3$ m, $W_{el}^{rc} = 0.30\text{-}0.60$ m.

EQUATION BLOCK 6-008

1. $v_{st}^{rc} = [g \times (G_s - 1) \times (d_p/1000)^2]/(18 \times \upsilon_l)$
2. $R_e = v_{st}^{rc} \times d_p/(\upsilon_l \times 1000)$

If $R_e < 1$

$v_{st}^{rc} = v_{st}^{rc}$ as Calculated (1)

If $1 < R_e < 1000$

$C_D = 24/R_e + 3/R_e + 0.34$

$v_{st}^{rc} = [4/3 \times g/C_D \times (G_s - 1)]^{0.5}$

If $R_e > 1000$

$v_{st}^{rc} = [3.3 \times g(G_s - 1) \times (d_p/1000)]^{0.5}$

3. $sor = v_{st}^{rc}/[(1/P_f^{rc}) \times ((1-\eta)^{-P_f^{rc}} - 1)]$
4. $Q_{ae}^{rc} = Q_a/N^{rc}$
5. $A^{rc} = Q_{ae}/(86400 \times sor)$
6. $W^{rc} = [A^{rc}/R_{lw}^{rc}]^{0.5}$
7. $L^{rc} = R_{lw}^{rc} \times W^{rc}$
8. $D_{sz}^{rc} = Q_{ae}^{rc} \times hrt^{rc}/(24 \times A^{rc})$
9. $v_{sc}^{rc} = k \times [g \times (G_s - 1) \times d_p^{rc}]^{0.5}$ [k = 3.0–4.5]
10. $D_{szm}^{rc} = Q_{ae}^{rc}/(86400 \times v_{sc}^{rc} \times W^{rc})$
11. If $D_{sz}^{rc} < D_{szm}^{rc}$, Put $D_{sz}^{rc} = D_{szm}^{rc}$

UNITS

v_{st}^{rc}, m/s; sor^{rc}, m/s, W^{rc}, m; L^{rc}, m; D^{rc}, m; v_{sc}^{rc}, m/s; D_{sz}^{rc}, m; hrt, h

EQUATION BLOCK 6-009

1. $N_s^{rc} = W^{rc} \times D^{rc}/(y_s^{rc})2$
2. If Slots are Circular

$d_s^{rc} = [(Q_{ae}^{rc} \times 4)/(v_s^{rc} \times N_s^{rc} \times \pi \times 86400)]^{0.5}$

3. If Slots are Square

$S_s^{rc} = [Q_{ae}^{rc}/(v_s^{rc} \times N_s^{rc}\ 86400)]^{0.5}$

EQUATION BLOCK 6-010

1. $H_t^{rc} = [(pf \times Q_{ae}^{rc})/(N_o^{rc} \times 0.61 \times L_o^{rc} \times W_o^{rc} \times (2g)^{0.5} \times 86400)]^2$

UNITS

H_t^{rc}, m;

EQUATION BLOCK 6-011

1. $N_{op}^{rc} - W_{1c}^{rc} \times L_{1c}^{rc}/(y_{op}^{rc})2$
2. $S_{op}^{rc} = [Q_{ae}^{rc}/(N_{op}^{rc} \times v_{op}^{rc} \times 86400)]^{0.5}$

UNITS

S_{op}^{rc}, m;

EQUATION BLOCK 6-012

1. $L_{1c}^{rc} = W^{rc}$
2. $H_{1w}^{rc} = [(Q_{ae}^{rc} \times 3)/(2 \times cd \times L_{ch}^{rc} \times (2g)^{0.5} \times 86400)]^{2/3}$

UNITS

L_{1c}^{rc}, m; H_{1w}^{rc}, m;

EQUATION BLOCK 6-013

1. $L_{ew}^{rc} = Q_{ae}^{rc}/R_w^{rc}$

If $W^{rc} > L_{ew}^{rc}$

$L_{wp} = W^{rc}$

Else

$L_o^{rc} = 0.2 \times L^{rc}$

If $L_{ew}^{rc} < 4 \times (L_o^{rc} + W^{rc})$

Provide Weir Plate on Both Sides of the Launder in the Outlet Zone

Else

$N_{ll}^{rc} = L_{ew}^{rc}/(2 \times L_o^{rc})$

$W_{ll}^{rc} = W^{rc}/(2 \times N_{ll}^{rc})$

2. $N_{nh}^{rc} = L_{ew}^{rc}/y_{nh}^{rc}$
3. $Y_2 = [(Q_{ae}/(2 \times 86400))^2/((W_{el}^{rc})^2 \times g)]^{1/3}$
4. $Y_1 = [Y_2^2 + 2 \times ((Q_{ae}^{rc}/86400) \times N)^2/(g \times (W_{el}^{rc})^2 \times Y_2)]^{1/2}$
5. $H_{nh}^{rc} = [Q_{ae}^{rc} \times 15/(8 \times cd \times (2g)^{0.5} \times 86400)]^{2/5}$
6. $D_{nh}^{rc} = 2 \times H_{nh}^{rc}$

7. $d_{ep}^{rc} = [(Q_{ae}^{rc} \times 4)/(v_{ep}^{rc} \times \pi \times 86400)]^{1/2}$

UNITS

L_{ew}^{rc}, m; Y_2, m; L_o^{rc}, m; H_{nh}^{rc}, m; D_{nh}^{rc}, m; d_{ep}^{rc}, m;

6.7 Design of Circular Radial Flow Settling Tank

1. Input: Average Flow, Q_a; % Water Lost in Desludging, P_{wd}^{crc}; Particle Size to be Removed, d_p^{crc}; Specific Gravity, G_s; Kinematic Viscosity, υ_l;m^2/s, Efficiency, η; Performance Factor, P_f; Height of Tank, H^{crc}; Weir Loading Rate, R_w^{crc}; Spacing of Ports, y_{pt}^{crc}; Velocity Through Port, v_{pt}^{crc}.
2. Put $N^{crc} = 1$
3. Compute Tank Parameters. Use Equation Block 6-014.
4. If Diameter of Clarifier exceeds 60 m , Put $N^{crc} = N^{crc} + 1$
5. Compute Inlet and Outlet Parameters. Use Equation Block 6-015.
6. Display Flow Rate, Number of Tank, Tank Parameters(Depth and Diameter), Inlet Parameters, Effluent Launder Parameters and Diameter of Effluent Pipe.

DEFAULT VALUES

$P_{wd}^{crc} = 2\%$, $d_p^{crc} = 0.8$ mm, Gs = 1.002, η=0.75, $\upsilon_l = 1.01 \times 10^{-6}\ m^2/s$, $P_f = 0.125$, $H^{crc} = 3.0$ m, $R_w^{crc} = 200\ m^3/d/m$, $y_{pt}^{crc} = 0.5$ m, $v_{pt}^{crc} = 0.3$ m/s.

RANGE

d_p^{crc} = 0.2-2.0 mm, η=0.75-0.90, P_f = 0.125-1.0, H^{crc} = 3.0-4.5 m, R_w^{crc} = 175-225 $m^3/d/m$, y_{pt}^{crc} = 0.2-0.6 m, v_{pt}^{crc} = 0.3-0.6 m/s.

EQUATION BLOCK 6-014

1. $Q_d^{crc} = [(Q_a \times 100)/(100 - P_{wd}^{crc})]$
2. $Q_{ae}^{crc} = Q_d^{crc}/N^{crc}$
3. $v_{st}^{crc} = g \times (G_s - 1) \times (d_p/1000)^2 /(18 \times \upsilon_l)$
4. $R_e = v_{st}^{crc} \times d_p/(1000 \times \upsilon_l)$

If $R_e < 1$

$v_{st}^{crc} = v_{st}^{crc}$ as Calculated in (3)

If $1 < R_e < 1000$

$C_D = 24/R_e + 3/R_e + 0.34$

$$v_{st}^{crc} = [4/3 \times g/C_D \times (G_s - 1)]^{1/2}$$

If $R_e > 1000$

$$v_{st}^{crc} = [3.3 \times g \times (G_s - 1) \times d_p/1000]^{1/2}$$

5. $sor^{crc} = v_{st}^{crc} \times 86400/[(1/P_f) \times ((1 - \eta)^{-P_f} - 1)]$
6. $A^{crc} = Q_{ae}^{crc}/sor^{crc}$
7. $d^{crc} = [4 \times A^{crc}/\pi]^{1/2}$
8. $hrt^{crc} = A^{crc} \times H^{crc} \times 24/Q_{ae}^{crc}$
9. $H_t^{crc} = H^{crc} + F_b^{crc}$

UNITS

Q_{ae}^{crc}, m^3/d; sor^{crc}, m/d; v_{st}^{crc}, m/s; d^{crc}, m; H_t^{crc}, m; hrt^{crc}, h.

EQUATION BLOCK 6-015

1. $d_b^{crc} = 0.24 \times d^{crc}$
2. $N_{pt}^{crc} = [\pi \times H^{crc} \times d_b^{crc}/(2 \times (y_{pt}^{crc})^2)]$
3. $A_{pt}^{crc} = Q_{ae}^{crc}/(v_{pt}^{crc} \times 86400)$
4. $d_{pt}^{crc} = [A_{pt}^{crc} \times 4/\pi \times N_{pt}^{crc}]^{1/2}$
5. $d_{rc}^{crc} = [(d_b^{crc})^2 + (d^{crc})^2]^{1/2}$
6. $R_w^{crc} = Q_{ae}^{crc}/(\pi \times d_{rc}^{crc})$
7. $W_{el}^{crc} = d_{rc}^{crc}/20$
8. $Y_1^{crc} = [3 \times (Q_{ae}^{crc}/86400)/(2 \times (g)^{0.5} \times W_{el}^{crc} + F_b^{crc})]^{2/3}$
9. $d_{ep}^{crc} = [4 \times Q_{ae}^{crc}/(\pi \times v_{ep}^{crc} \times 86400)]^{1/2}$

UNITS

d_b^{crc}, m; A_{pt}^{crc}, m^2; d_{pt}^{crc}, m; d_{rc}^{crc}, m; R_w^{crc}, $m^3/d/m$; W_{el}^{crc}, m; Y_1^{crc}, m; d_{ep}^{crc}, m;

6.8 Design of Circumferential Flow Circular Clarifier

1. Input: Average Flow, Q_a; Surface Overflow Rate, sor^{cc}; Weir Loading, R_{wm}^{cc}; Velocity in Ports, v_{pt}^{cc}; Height of Tank, H^{cc}; Ratio of Width of Effluent launder to Diameter of Tank, R_{et}^{cc}; Free Board, F_b^{cc};
2. Put $N^{cc} = 1$;
3. Compute Flow Rate in Each Clarifier, Diameter, Height of Port Opening, Effluent Launder Parameters (Width and Depth), Diameter of Influent Pipe and Weir Loading. Use Equation Block 6-016.

4. If Weir Loading Rate > Maximum Weir Loading Rate then Put $N^{cc} = N^{cc}+1$ or If Diameter of Clarifier > 60m then Put $N^{cc} = N^{cc} + 1$.
5. Display Average Flow, Number of Clarifiers, Clarifier Parameters, Effluent Launder Parameters, Height of Port Opening, Diameter of Influent Pipe.

DEFAULT VALUES

$Sor^{cc} = 35\ m^3/m^2/d$, $R_{wm}^{cc} = 165\ m^3/d/m$, $v_{pt}^{cc} = 0.3\ m/s$, $H^{cc} = 3.0\ m$; $R_{et}^{cc} = 0.05$, $F_b^{cc} = 0.3m$

RANGE

$Sor^{cc} = 30\text{-}45\ m^3/m^2/d$, $v_{pt}^{cc} = 0.3\text{-}0.45\ m/s$, $H^{cc} = 3.0\text{-}4.5\ m$;

EQUATION BLOCK 6-016

1. $Q_{ae}^{cc} = Q_a/N^{cc}$
2. $d^{cc} = [(4 \times Q_{ae}^{cc})/(sor^{cc} \times \pi)]^{1/2}$
3. $W_{el}^{cc} = R_{el}^{cc} \times d^{cc}$
4. $H_{pt}^{cc} = [Q_{ae}^{cc}/(v_{pt}^{cc} \times \pi \times d^{cc} \times 86400)]$
5. $R_w^{cc} = Q_{ae}^{cc}/(\pi \times d^{cc})$
6. $Y_1^{cc} = [3 \times (Q_{ae}^{cc}/86400)/(2 \times (g)^{0.5} \times (0.05 \times d^{cc}))]^{2/3}$
7. $d_{ip}^{cc} = [4 \times Q_{ae}^{cc}/(\pi \times v_{pt}^{cc} \times 86400)]^{1/2}$

UNITS

Q_{ae}^{cc}, m^3/d; d^{cc}, m; W_{el}^{cc}, m; H_{pt}^{cc}, m; R_w^{cc}, $m^3/d/m^2$; Y_1^{cc}, m; d_{ip}^{cc}, m;

6.9 Design of Inline Blender Rapid Mix Unit

1. Input: Average Flow, Q_a; Temperature, T_a; Velocity Gradient, G^{ir}; Hydraulic Retention Time, hrt^{ir}; Ratio of Length to Depth of Tank, R_{ld}^{ir}; Ratio of Length to Width of Blade, R_{lwb}^{ir}; Efficiency of Motor and Drive, η_m^{ir}; Dynamic Viscosity, μ_l; Ratio of Length of Blade to Width of Tank, R_{bw}^{ir}; Number of Blades, N_{bd}^{ir}; Drag Coefficient, C_D.
2. Compute Tank Parameters(Length, Width and Height), Blade Parameters(Length, Height and Number of Blades), Rotational Speed of Shaft and Motor Power. Use Equation Block 6-017.

3. Display Flow Rate, Temperature, Velocity Gradient, Residence Time, Tank Parameters, Blade Parameters, Rotational Speed of Shaft and Motor Power.

DEFAULT VALUES

$G^{ir} = 5000$ /s, $hrt^{ir} = 0.5$ s, $R_{ld}^{ir} = 2.0$, $R_{lwb}^{ir} = 6.0$, $\eta_m^{ir} = 0.8$, $R_{bw}^{ir} = 0.8$, $N_{bd}^{ir} = 4.0$.

RANGE

$G^{ir} = 3000\text{-}5000$ /s, $hrt^{ir} = 0.5\text{-}1.0$ s, $R_{ld}^{ir} = 2.0\text{-}4.0$, $R_{lwb}^{ir} = 4.0\text{-}10.0$, $\eta_m^{ir} = 0.75\text{-}1.0$, $R_{bw}^{ir} = 0.4\text{-}0.8$, $N_{bd}^{ir} = 4.0\text{-}10.0$.

EQUATION BLOCK 6-017

1. $V^{ir} = Q_a \times hrt^{ir} / 86400$
2. $H^{ir} = [V^{ir}/(R_{ld}^{ir})^2]^{1/3}$
3. $L^{ir} = R_{ld}^{ir} \times H^{ir}$
4. $W^{ir} = L^{ir}$
5. $L_{bd}^{ir} = R_{bw}^{ir} \times W^{ir}$
6. $W_{bd}^{ir} = L_{bd}^{ir}/R_{lwb}^{ir}$
7. $P_i^{ir} = 0.0016578\, e^{-0.02145T_a} \times (G^{ir})^2 \times V^{ir}$
8. $\omega^{ir} = 60 \times [(2 \times N_{bd}^{ir} \times P_i^{ir})/(C_D \times L_{bd}^{ir} \times W_{bd}^{ir} \times N_{bd}^{c} \times 1000 \times \pi \times (L_{bd}^{ir})^3)]^{1/3}$
9. $P_m^{ir} = P_i^{ir}/\eta_m^{ir}$

UNITS

G^{ir}, /s; V^{ir}, m^3; L^{ir}, m; W^{ir}, m; H^{ir}, m; L_{bd}^{ir}, m; W_{bd}^{ir}, m; ω^{ir}, rpm; P_m^{ir}, watt.

6.10 Design of Turbine Type Rapid Mix Unit

1. Input: Average Flow, Q_a; Temperature, T_a; Hydraulic Retention Time, hrt^{tr}; Velocity Gradient, G^{tr}; Efficiency of Motor, η_m^{tr}; Ratio of Diameter to Depth of Tank, R_{dd}^{tr}; Ratio of Length to Width of Blade, R_{lwb}^{tr}; Number of Blades, N_{bd}^{tr}; Ratio of Length of Stator to Diameter of Tank, R_{lds}^{tr}; Ratio of Length of Blade to Diameter of Tank., R_{ldb}^{tr};
2. Compute Tank Parameters(Volume, Diameter & Depth), Blade Parameters(Length, Width and Number of Blades), Rotational Speed of Shaft and Motor Power. Use Equation Block 6-018.

3. Display Flow Rate, Temperature, Hydraulic Retention Time, Velocity Gradient, Tank Parameters, Blade Parameters, Rotational Speed of Shaft and Motor Power.

DEFAULT VALUES

$hrt^{tr} = 77$ s, $G^{tr} = 700$ /s, $\eta_m^{tr} = 0.80$, $R_{dd}^{tr} = 1.0$, $R_{lwb}^{tr} = 8.0$, $N_{bd}^{tr} = 6.0$, $R_{lds}^{tr} = 0.1$, $R_{ldb}^{tr} = 0.4$.

RANGE

$hrt^{tr} = 50\text{-}100$ s, $G^{tr} = 600\text{-}1000$ /s, $\eta_m^{tr} = 0.75\text{-}1.0$, $R_{dd}^{tr} = 1.0\text{-}1.5$, $R_{lwb}^{tr} = 6.0\text{-}10.0$, $N_{bd}^{tr} = 4.0\text{-}10.0$, $R_{lds}^{tr} = 0.1\text{-}0.2$, $R_{ldb}^{tr} = 0.2\text{-}0.4$.

EQUATION BLOCK 6-018

1. $V^{tr} = Q_a \times hrt^{tr}/86400$
2. $d^{tr} = [4 \times V^{tr} \times R_{dd}^{tr}/\pi]^{1/3}$
3. $D^{tr} = d^{tr}/R_{dd}^{tr}$
4. $P_i^{tr} = 0.0016578\, e^{-0.02145T_a} \times (G^{tr})^2 \times V^{tr}$
5. $L_{sta}^{tr} = R_{lds}^{tr} \times d^{tr}$
6. $L_{bd}^{tr} = R_{ldb}^{tr} \times d^{tr}$
7. $W_{bd}^{tr} = L_{bd}^{tr}/R_{lwb}^{tr}$
8. $\omega^{tr} = 60 \times [(2 \times P_i^{tr})/(C_D \times L_{bd}^{tr} \times W_{bd}^{tr} \times N_{bd}^{tr} \times 1000 \times \pi \times (L_{bd}^{tr})^3)]^{1/3}$
9. $P_m^{tr} = P_i^{tr}/\eta_m^{tr}$

UNITS

V^{tr}, m^3; D^{tr}, m; d^{tr}, m; L_{bd}^{tr}, m; W_{bd}^{tr}, m; ω^{tr}, rpm; P_i^{tr}, watt; P_m^{tr}, watt;

6.11 Design of Vertical Baffled Rapid Mix Unit

1. Input: Average Flow, Q_a; Hydraulic Retention Time, hrt^{vr}; Ratio of Length to Width of Tank, R_{lw}^{vr}; Ratio of Width to Height of Tank, R_{wh}^{vr}; Velocity in Channels, v_{ch}^{vr}.
2. Compute Tank Parameters(Length, Width and Height), Channel Width. Use Equation Block 6-019.
3. Compute Channel Parameters(Length, Width and Number), Length of Baffle, Velocity in Channels, Velocity in Slots. Use Equation Block 6-020.

4. Compute Head Loss in Tank, Water Head Over Outlet Baffle, Velocity Gradient. Use Equation Block 6-021.
5. Display Flow Rate, Tank Parameters, Baffle Parameters, Channel Parameters, Head Loss in Tank, Head Over Outlet Weir, Velocity Gradient.

DEFAULT VALUES

$hrt^{vr} = 20$ s, $R_{lw}^{vr} = 5.0$, $R_{wh}^{vr} = 1.0$, $v_{ch}^{vr} = 0.6$ m/s.

RANGE

$hrt^{vr} = 20\text{-}30$ s, $R_{lw}^{vr} = 3.0\text{-}8.0$, $R_{wh}^{vr} = 1.0\text{-}2.0$, $v_{ch}^{vr} = 0.6\text{-}0.9$ m/s.

EQUATION BLOCK 6-019

1. $V^{vr} = Q_a \times hrt^{vr}/86400$
2. $W^{vr} = [R_{wh}^{vr} \times V^{vr}/R_{lw}^{vr}]^{1/3}$
3. $H^{vr} = W^{vr}/R_{wh}^{vr}$
4. $L^{vr} = R_{lw}^{vr} \times W^{vr}$
5. $W_{ch}^{vr} = Q_a/(W^{vr} \times v_{ch}^{vr} \times 86400)$

UNITS

V^{vr}, m^3; L^{vr}, m; W^{vr}, m; H^{vr}, m; W_{ch}^{vr}, m;

EQUATION BLOCK 6-020

1. $N_{ch}^{vr} = Int(L^{vr}/W_{ch}^{vr}) + 1$
2. $L_{ch}^{vr} = W^{vr}$
3. $W_{ch}^{vr} = Q_a/(W^{vr} \times v_{ch}^{vr} \times 86400)$
4. $L_b^{vr} = (L_{ch}^{vr} - W_{ch}^{vr})/2$
5. $v_{ch}^{vr} = Q_a/(W_{ch}^{vr} \times W^{vr} \times 86400)$
6. $v_s^{vr} = 2 \times v_{ch}^{vr}$

UNITS

L_{ch}^{vr}, m; L_b^{vr}, m; v_{ch}^{vr}, m/s; v_s^{vr}, m/s;

EQUATION BLOCK 6-021

1. $G^{vr} = 2790 \times (hrt^{vr})^{-0.35}$

2. $H_l^{vr} = 0.0153 \times (G^{vr} \times hrt^{vr})^{0.47} + N_{ch}^{vr} \times L_{ch}^{vr} \times 1/50$
3. $H_w^{vr} = [(3 \times Q_a)/(86400 \times 2 \times 0.61 \times (2g)^{1/2} \times W^{vr})]^{2/3}$

UNITS

H_l^{vr}, m; G^{vr}, /s; H_w^{vr}, m;

6.12 Design of Horizontal Baffled Rapid Mix Unit

1. Input: Average Flow, Q_a; Hydraulic Retention Time, hrt^{hr}; Ratio of Length to Width of Tank, R_{lw}^{hr}; Ratio of Width to Height of Tank, R_{wh}^{hr}; Velocity in Channels, v_{ch}^{hr}.
2. Compute Tank Parameters(Length, Width and Height), Channel Width. Use Equation Block 6-022.
3. Compute Channel Parameters(Length, Width and Number), Length of Baffle, Velocity in Channels and Velocity in Slots. Use Equation Block 6-023.
4. Compute Head Loss in Tank, Water Head Over Outlet Baffle and Velocity Gradient. Use Equation Block 6-024.
5. Display Flow Rate, Tank Parameters, Baffle Parameters, Channel Parameters, Head Loss in Tank, Head Over Outlet Weir, Velocity Gradient.

DEFAULT VALUES

$hrt^{hr} = 20$ s, $R_{lw}^{hr} = 5.0$, $R_{wh}^{hr} = 1.0$, $v_{ch}^{hr} = 0.6$ m/s.

RANGE

$hrt^{hr} = 20\text{-}30$ s, $R_{lw}^{hr} = 3.0\text{-}8.0$, $R_{wh}^{hr} = 1.0\text{-}2.0$, $v_{ch}^{hr} = 0.6\text{-}0.9$ m/s.

EQUATION BLOCK 6-022

6. $V^{hr} = Qa \times hrt^{hr}/86400$
7. $W^{hr} = [R_{wh}^{hr} \times V^{hr}/R_{lw}^{hr}]^{1/3}$
8. $H^{hr} = W^{hr}/R_{wh}^{hr}$
9. $L^{hr} = R_{lw}^{hr} \times W^{hr}$

UNITS

V^{hr}, m^3; L^{hr}, m; W^{hr}, m; H^{hr}, m; W_{ch}^{hr}, m;

EQUATION BLOCK 6-023

7. $N_{ch}^{hr} = Int(L^{hr}/W_{ch}^{hr}) + 1$
8. $L_{ch}^{hr} = W^{hr}$
9. $W_{ch}^{hr} = Q_a/(W^{hr} \times v_{ch}^{hr} \times 86400)$
10. $L_b^{hr} = (L_{ch}^{hr} - W_{ch}^{hr})/2$
11. $v_{ch}^{hr} = Q_a/(W_{ch}^{hr} \times W^{hr} \times 86400)$
12. $v_s^{hr} = 2 \times v_{ch}^{hr}$

UNITS

L_{ch}^{hr}, m; L_b^{hr}, m; v_{ch}^{hr}, m/s; v_s^{hr}, m/s;

EQUATION BLOCK 6-024

4. $G^{hr} = 2790 \times (hrt^{hr})^{-0.35}$
5. $H_l^{hr} = 0.0153 \times (G^{hr} \times hrt^{hr})^{0.47} + N_{ch}^{hr} \times L_{ch}^{hr} \times 1/50$
6. $H_w^{hr} = [(3 \times Q_a)/(86400 \times 2 \times 0.61 \times (2g)^{1/2} \times W^{hr})]^{2/3}$

UNITS

H_l^{hr}, m; G^{hr}, /s; H_w^{hr}, m;

6.13 Design of Inline Blender Flocculator

1. Input: Average Flow, Q_a; Temperature, T_a; Alum Dose, Al^{if}; Hydraulic Retention Time, hrt^{if}; Ratio of Length to Depth of Tank, R_{ld}^{if}; Ratio of Length to Width of Blade, R_{lwb}^{if}; Efficiency of Motor and Drive, η_m^{if}; Number of Compartments, N_{co}^{if}; Ratio of Length of Blade to Width of Tank, R_{wb}^{if}; Number of Blades, N_{bd}^{if}.
2. Compute Optimum Velocity Gradient. Use Equation Block 6-021.
3. Input: Velocity Gradient in Each Compartment.
4. Compute Tank Parameters(Length, Width & Depth), Blade Parameters(Length, Height, Number of Blades), Rotational Speed of Shaft, Motor Power. Use Equation Block 6-025.
5. Display Flow, Temperature, Optimum Velocity Gradient, Velocity Gradient in Each Compartment, Blade Parameters(Number, Height, Length), Tank Parameters, Rotational Speed of Shaft, Motor Power.

DEFAULT VALUES

Al^{if} = 20 mg/l, hrt^{if} = 20 min, N_{co}^{if} = 4, R_{ld}^{if} = 1.0, R_{lwb}^{if} = 6.0, η_m^{if} = 0.8, R_{bw}^{if} = 0.4, N_{bd}^{if} = 4.0.

RANGE

Al^{if} = 15-40 mg/l, hrt^{if} = 20-30 min, N_{co}^{if} = 1-4, R_{ld}^{if} = 1.0-2.0, R_{lwb}^{if} = 4.0-10.0, η_m^{if} = 0.75-1.0, R_{bw}^{if} = 0.2-0.8, N_{bd}^{if} = 4.0-10.0.

EQUATION BLOCK 6-025

1. $G^{if} = \mathrm{Int}(44 \times 10^5/Al^{if} \times hrt^{if})^{1/2.8}$
2. $hrt_{co}^{if} = hrt^{if}/N_{co}^{if}$
3. $V_{co}^{if} = Q_a \times hrt_{co}^{if}/1440$
4. $D_{co}^{if} = [V_{if}/R_{ld}^{if}]^{1/3}$
5. $S_{co}^{if} = D_{co}^{if} \times R_{lw}^{if}$
6. $P_{ic}^{if} = 0.0016578\ e^{-0.02145T_a} \times (G_{ci}^{if})^2 \times V_{co}^{if}$
7. $P_r^{if} = \sum P_{ic}^{if}$
8. $P_m^{if} = P_r^{if}/\eta_m^{if}$
9. $L_{bd}^{if} = R_{bw}^{if} \times W_{co}^{if}$
10. $W_{bd}^{if} = L_{bd}^{if}/R_{lwb}^{if}$
11. $\omega^{if} = 60 \times [(2 \times P_m^{if})/(C_D \times L_{bd}^{if} \times W_{bd}^{if} \times N_{bd}^{if} \times 1000 \times \pi \times (L_{bd}^{if})^3)]^{1/3}$

UNITS

G^{if}, /s; hrt^{if}, min; V_{co}^{if}, m^3; S_{co}^{if}; H_{co}^{if}, m; P_r^{if}, watt; L_{bd}^{if}, m; W_{bd}^{if}, m; $\omega^{if}t$, rpm;

6.14 Design of Paddle Type Flocculator

1. Input: Average Flow, Q_a; Temperature, T_a; Alum Dose, Al^{pf}; Hydraulic Retention Time, hrt^{pf}; Ratio of Length to Width of Tank, R_{lw}^{pf}; Ratio of Width to Depth of Tank, R_{wd}^{pf}; Efficiency of Motor and Drive, η_m^{pf}; Number of Paddles per Shaft, N_{ps}^{pf}; Tip Velocity of Paddle, v_i^{pf}; Length of Shaft, L_{sh}^{pf}; Spacing of Paddles, y_{pd}^{pf}; Rotational Speed of Flocculator, ω^{pf}, Velocity Gradient,G^{pf}.

2. Compute Tank Parameters(Length, Width and Depth). Use Equation Block 6-026.
3. Compute Power Requirement, Paddle Parameters. Use Equation Block 6-027.
4. Display Flow Rate, Temperature, Velocity Gradient, Tank Parameters, Paddle Parameters, Shaft Parameters, Rotational Speed of Shaft, Motor Power.

DEFAULT VALUES

hrt^{pf} = 30 min, Al^{pf} = 25 mg/l, η_m^{pf} = 0.75, R_{lw}^{pf} = 3.0, R_{wd}^{pf} = 4.0, v_i^{pf} = 0.4 m/s, G^{pf} = 50.

RANGE

hrt^{pf} = 15-30 min, Al^{pf} = 20-30 mg/l, η_m^{pf} = 0.75-1.0, R_{lw}^{pf} = 3.0-5.0, R_{wd}^{pf} = 4.0-6.0, v_i^{pf} = 0.2 –0.8m/s, G^{pf} = 10 – 75 /s.

EQUATION BLOCK 6-026

1. $V^{pf} = hrt^{pf} \times Q_a/1440$
2. $L^{pf} = [(R_{lw}^{pf})^2 \times R_{wd}^{pf} \times V^{pf}]^{1/3}$
3. $W^{pf} = L^{pf}/R_{lw}^{pf}$
4. $D^{pf} = W^{pf}/R_{wd}^{pf}$
5. $N_{sh}^{pf} = 0.8 \times L^{pf}/L_{sh}^{pf}$

UNITS

G^{pf}, /s; V^{pf}, m^3; L^{pf}, m; W^{pf}, m; D^{pf}, m;

EQUATION BLOCK 6-027

1. $P_i^{pf} = 0.0016578\ e^{-0.02145T_a} \times (G^{pf})^2 \times V^{pf}$
2. $A_{pd}^{pf} = [2 \times P_r^{pf}/(C_D \times \rho_l^{pf} \times (0.75 \times v_i^{pf})^3)]$
3. $W_{pd}^{pf} = A_{pd}^{pf}/(N_{pd}^{pf} \times N_{ps}^{pf})$
4. $d_{pd}^{pf} = 0.8 \times D^{pf}$
5. $\omega^{pf} = [(v_i^{pf} \times 2 \times 60)/(2 \times \pi \times d_{pd}^{pf})]$

UNITS

P_i^{pf}, watt; A_{pd}^{pf}, m^2; d_{pd}^{pf}, m; ω^{pf}, rpm;

6.15 Design of Flat Blade Turbine Flocculator

1. Input: Average Flow, Q_a; Temperature, T_a; Hydraulic Retention Time, hrt^{ft}; Velocity Gradient, G^{ft}; Efficiency of Motor and Drive, $\eta_m{}^{ft}$; Ratio of Diameter to Depth of Tank, $R_{dd}{}^{ft}$; Number of Blades, $N_{bd}{}^{ft}$; Ratio of Length of Blade to Diameter of Tank, $R_{ldb}{}^{ft}$; Ratio of Length to Width of Blade, $R_{lwb}{}^{ft}$.
2. Compute Tank Parameters(Volume, Diameter and Depth), Blade Parameters(Length, Width and Number of Blades) and Power Requirement. Use Equation Block 6-028.
3. Display Flow Rate, Temperature, Hydraulic Retention Time, Velocity Gradient, Tank Parameters, Blade Parameters, Rotational Speed of Shaft and Motor Power.

DEFAULT VALUES

$hrt^{ft} = 1500$ s, $G^{ft} = 50$ /s, $\eta_m{}^{ft} = 0.75$, $R_{dd}{}^{ft} = 1.0$, $N_{bd}{}^{ft} = 4.0$, $R_{ldb}{}^{ft} = 0.4$, $R_{lwb}{}^{ft} = 6.0$

RANGE

$hrt^{ft} = 1500\text{-}1800$ s, $G^{ft} = 10 - 75$ /s, $\eta_m{}^{ft} = 0.75\text{-}1.0$, $R_{dd}{}^{ft} = 1.0\text{-}1.5$, $N_{bd}{}^{ft} = 2.0\text{-}8.0$, $R_{ldb}{}^{ft} = 0.2\text{-}0.4$, $R_{lwb}{}^{ft} = 4.0\text{-}10.0$

EQUATION BLOCK 6-028

1. $V^{ft} = Q_a \times hrt^{ft}/86400$
2. $d^{ft} = [4 \times V^{ft} \times R_{dd}{}^{ft}/\pi]^{1/3}$
3. $P_i{}^{ft} = 0.0016578\ e^{-0.02145T_a} \times (G^{ft})^2 \times V^{ft}$
4. $D^{ft} = d^{ft}/R_{dd}{}^{ft}$
5. $L_{bd}{}^{ft} = R_{ldb}{}^{ft} \times d^{ft}$
6. $W_{bd}{}^{ft} = L_{bd}{}^{ft}/R_{lwb}{}^{ft}$
7. $A_{bd}{}^{ft} = L_{bd}{}^{ft} \times W_{bd}{}^{ft}$
8. $\omega^{ft} = 60 \times [(2 \times P_i{}^{ft})/(N_{bd}{}^{ft} \times C_D \times A_{bd}{}^{ft} \times 1000 \times \pi \times (L_{bd}{}^{ft})^3)]^{1/3}$
9. $P_m{}^{ft} = P_i{}^{ft}/\eta_m{}^{ft}$

UNITS

V^{ft}, m^3; d^{ft}, m; D^{ft}, m; $L_{bd}{}^{ft}$, m; $W_{bd}{}^{ft}$, m; $A_{bd}{}^{ft}$, m^2; ω^{ft}, rpm; $P_m{}^{ft}$, watt;

6.16 Design of Vertical Baffled Flocculator

1. Input: Average Flow, Q_a; Temperature, T_a; Hydaulic Retention Time, hrt^{vf}; Length to Width Ratio of Tank, R_{lw}^{vf}; Ratio of Width to Height of Tank, R_{wh}^{vf}; Coagulant.
2. Put $v_{ch}^{vf} = 0.3$ m/s.
3. Compute Tank Parameters (Length, Width and Height). Use Equation Block 6-029.
4. Compute Channel Parameters (Width, Number and Length), Length of Baffle, Velocity in Channels, Velocity in Slots, Head Loss in Channels and Velocity Gradient. Use Equation Block 6-030.
5. If Coagulant = Alum then go to 5A else 5B

5A If G^{vf} x $hrt^{vf} < 2 \times 10^4$ then go to 5A1 else 5A2

5A1 $v_{ch}^{vf} = v_{ch}^{vf} + 0.01$. Go to 6.

5A2 If G^{vf} x $hrt^{vf} > 6 \times 10^4$ then go to 5A3 else to 7.

5A3 $v_{ch}^{vf} = v_{ch}^{vf} - 0.01$. Go to 6

5B If G^{vf} x $hrt^{vf} < 10^5$ go to 5B1 else to 5B2

5B1 $v_{ch}^{vf} = v_{ch}^{vf} + 0.01$. Go to 6.

5B2 If G^{vf} x $hrt^{vf} > 1.5 \times 10^5$ then go to 5B3 else to 7.

5B3 $v_{ch}^{vf} = v_{ch}^{vf} - 0.01$. Go to 6.

6. Compute Head Loss in Tank, Water Head Over Outlet Baffle. Use Equation Block 6-031.
7. Display Average Flow, Coagulant, Tank Parameters, Baffle Parameters, Channel Parameters, Head Loss in Tank, Water Head Over Baffle, Velocity Gradient, Length of Baffle and Length of Slots.

DEFAULT VALUES

$hrt^{vf} = 1000$s, $R_{lw}^{vf} = 5$, $R_{wh}^{vf} = 1.0$;

RANGE

$hrt^{vf} = 1000\text{-}1500$ s, $R_{lw}^{vf} = 4\text{-}6$, $R_{wh}^{vf} = 1.0\text{-}2.0$;

EQUATION BLOCK 6-029

1. $V^{vf} = Q_a \times hrt^{vf}$
2. $W^{vf} = [(R_{wh}^{vf} \times V^{vf})/R_{lw}^{vf})^{1/3}$
3. $H^{vf} = W^{vf}/R_{wh}^{vf}$

4. $L^{vf} = V^{vf}/(H^{vf} \times W^{vf})$
UNITS
V^{vf}, m^3; W^{vf}, m; L^{vf}, m; H^{vf}, m;

EQUATION BLOCK 6-030
1. $W_{ch}^{vf} = [Q_a/(W^{vf} \times v_{ch}^{vf})]$
2. $N_{ch}^{vf} = \mathrm{Int}(L^{vf}/W_{ch}^{vf}) + 1$
3. $L_{ch}^{vf} = H^{vf}$
4. $L_b^{vf} = L_{ch}^{vf} - W_{ch}^{vf}/2$
5. $v_{ch}^{vf} = Q_a/(W^{vf} \times W_{ch}^{vf})$
6. $v_s^{vf} = 2 \times v_{ch}^{vf}$
7. $H_{lc}^{vf} = [\{N_{ch}^{vf} \times (v_{ch}^{vf})^2\} + \{(N_{ch}^{vf} - 1) \times (v_s^{vf})^2\}]$
8. $G^{vf} = [\rho \times g \times H_{lc}^{vf}/\{(0.0016578\ e^{-0.02145T}{}_a) \times hrt^{vf}\}]$
UNITS
W_{ch}^{vf}, m; L_{ch}^{vf}, m; H_{ch}^{vf}, m; H_{lc}^{vf}, m; v_{ch}^{vf}, m/s; v_s^{vf}, m/s; G^{vf}, /s

EQUATION BLOCK 6-031
1. $H_l^{vf} = H_{lc}^{vf} + N_{ch}^{vf} \times L_{ch}^{vf} \times 1/50$
2. $H_b^{vf} = [(3 \times Q_a)/\{2 \times cd \times (2 \times g)^{1/2} \times W^{vf}\}]^{2/3}$
UNITS
H_l^{vf}, m; H_b^{vf}, m;

6.17 Design of Horizontal Baffled Flocculator

1. Input: Average Flow, Q_a; Temperature, T_a; Hydaulic Retention Time, hrt^{hf}; Length to Width Ratio of Tank, R_{lw}^{hf}; Ratio of Width to Height of Tank, R_{wh}^{hf}; Coagulant.
2. Put $v_{ch}^{hf} = 0.3$ m/s.
3. Compute Tank Parameters (Length, Width and Height). Use Equation Block 6-032.

4. Compute Channel Parameters (Width, Number and Length), Length of Baffle, Velocity in Channels, Velocity in Slots, Head Loss in Channels and Velocity Gradient. Use Equation Block 6-033.

5. If Coagulant = Alum then go to 5A else 5B

5A If G^{hf} x $hrt^{hf} < 2 \times 10^4$ then go to 5A1 else 5A2

5A1 $v_{ch}{}^{hf} = v_{ch}{}^{hf} + 0.01$. Go to 6.

5A2 If G^{hf} x $hrt^{hf} > 6 \times 10^4$ then go to 5A3 else to 7.

5A3 $v_{ch}{}^{hf} = v_{ch}{}^{hf} - 0.01$. Go to 6

5B If G^{hf} x $hrt^{hf} < 10^5$ go to 5B1 else to 5B2

5B1 $v_{ch}{}^{hf} = v_{ch}{}^{hf} + 0.01$. Go to 6.

5B2 If G^{hf} x $hrt^{hf} > 1.5 \times 10^5$ then go to 5B3 else to 7.

5B3 $v_{ch}{}^{hf} = v_{ch}{}^{hf} - 0.01$. Go to 6.

6. Compute Head Loss in Tank, Water Head Over Outlet Baffle. Use Equation Block 6-034.

7. Display Average Flow, Coagulant, Tank Parameters, Baffle Parameters, Channel Parameters, Head Loss in Tank, Water Head Over Baffle, Velocity Gradient, Length of Baffle and Length of Slots.

DEFAULT VALUES

$hrt^{hf} = 1000s$, $R_{lw}{}^{hf} = 5$, $R_{wh}{}^{hf} = 1.0$;

RANGE

$hrt^{hf} = 1000\text{-}1800$ s, $R_{lw}{}^{hf} = 4\text{-}6$, $R_{wh}{}^{hf} = 1.0\text{-}2.0$;

EQUATION BLOCK 6-032

1. $V^{hf} = Q_a \times hrt^{hf}/86400$
2. $W^{hf} = [(R_{wh}{}^{hf} \times V^{hf})/R_{lw}{}^{hf})^{1/3}$
3. $H^{hf} = W^{hf}/R_{wh}{}^{hf}$
4. $L^{hf} = V^{hf}/(H^{hf} \times W^{hf})$

UNITS

V^{hf}, m^3; W^{hf}, m; L^{hf}, m; H^{hf}, m;

EQUATION BLOCK 6-033

1. $W_{ch}{}^{hf} = [Q_a/(W^{hf} \times v_{ch}{}^{hf})]$
2. $N_{ch}{}^{hf} = \mathrm{Int}(L^{hf}/W_{ch}{}^{hf}) + 1$

3.	$L_{ch}^{hf} = H^{hf}$
4.	$L_b^{hf} = L_{ch}^{hf} - W_{ch}^{hf}/2$
5.	$v_{ch}^{hf} = Q_a/(W^{hf} \times W_{ch}^{hf})$
6.	$v_s^{hf} = 2 \times v_{ch}^{hf}$
7.	$H_{lc}^{hf} = [\{N_{ch}^{hf} \times (v_{ch}^{hf})^2\} + \{(N_{ch}^{hf} - 1) \times (v_s^{hf})^2\}]$
8.	$G^{hf} = [\rho \times g \times H_{lc}^{hf}/\{(0.0016578\, e^{-0.021451}{}_{a}) \times hrt^{hf}\}]$

UNITS

W_{ch}^{hf}, m; L_{ch}^{hf}, m; H_{ch}^{hf}, m; H_{lc}^{hf}, m; v_{ch}^{hf}, m/s; v_s^{hf}, m/s; G^{hf}, /s

EQUATION BLOCK 6-034

1.	$H_l^{hf} = H_{lc}^{hf} + N_{ch}^{hf} \times L_{ch}^{hf} \times 1/50$
2.	$H_b^{hf} = [(3 \times Q_a)/\{2 \times cd \times (2 \times g)^{1/2} \times W^{hf}\}]^{2/3}$

UNITS

H_l^{hf}, m; H_b^{hf}, m;

6.18 Design of Slow Sand Filter

1. Input: Average Flow, Q_a; Temperature, T_a; Filtration Rate, R_f^{sf}; Diameter of Laterals, d_l^{sf}; Free Board, F_b^{sf}; Water Depth Over Filter Bed, D_w^{sf}; Length to Width Ratio of Filter, R_{lw}^{sf}; Effective Size of Sand, E_s^{sf}; Uniformity Coefficient of Sand, U_s^{sf}; Ratio of Area of Perforation to Area of Filter, R_{pf}^{sf}; Ratio of Area of Laterals to Area of Perforations, R_{lp}^{sf}; Ratio of Area of Main Pipe to Area of Laterals, R_{ml}^{sf}; Sand Depth, D_s^{sf}; Gravel Depth, D_g^{sf}.
2. Compute Total Surface Area of Filter, Number of Filters. Use Equation Block 6-035
3. Compute Filter Bed Parameters(Width and Length), Number of Laterals, Spacing of Laterals, Spacing of Orfices, Diameter of Orfices, Diameter of Main Pipe, Height of Filter Box and Head Loss in Filter. Use Equation Block 6-036.
4. Display Flow Rate, Filter Parameters, Lateral Parameters, Orfice Parameters, Diameter of Main Pipe and Head Loss in Filter.

DEFAULT VALUES

$d_l^{sf} = 0.10$ m, $R_f^{sf} = 0.25$ m^3/m^2/h, $D_w^{sf} = 1.0$ m, $R_{lw}^{sf} = 3.0$, $E_s^{sf} = 0.3$ mm, $U_s^{sf} = 2.5$, $R_{pf}^{sf} = 0.003$, $R_{lp}^{sf} = 3.0$, $R_{ml}^{sf} = 1.75$, $D_s^{sf} = 1.2$ m, $D_g^{sf} = 0.3$ m, $F_b^{sf} = 0.3$ m.

RANGE

$d_l^{sf} = 0.10\text{-}0.20$ m, $R_f^{sf} = 0.15\text{-}0.40$ m^3/m^2/h, $D_w^{sf} = 1.0\text{-}1.5$ m, $R_{lw}^{sf} = 2.0\text{-}5.0$, $E_s^{sf} = 0.15\text{-}0.35$ mm, $U_s^{sf} = 1.5\text{-}3.0$, $R_{pf}^{sf} = 0.003\text{-}0.004$, $R_{lp}^{sf} = 2.0\text{-}4.0$, $R_{ml}^{sf} = 1.5\text{-}2.0$, $D_s^{sf} = 1.2\text{-}1.4$ m, $D_g^{sf} = 0.15\text{-}0.30$ m, $F_b^{sf} = 0.3\text{-}0.5$ m.

EQUATION BLOCK 6-035

1. $A_t^{sf} = Q_a/(R_f^{sf} \text{ x } 24)$
2. $N^{sf} = \text{Int}[1/4 \text{ x } (Q_a/24)^{1/2}]$
3. $A^{sf} = A_t^{sf}/N^{sf}$

UNITS

Q_a, m^3/d; A_t^{sf}, m^2; A^{sf}, m^2;

EQUATION BLOCK 6-036

1. $W^{sf} = [A^{sf}/R_{lw}^{sf}]^{1/2}$
2. $L^{sf} = R_{lw}^{sf} \text{ x } W^{sf}$
3. $A_{pf}^{sf} = R_{pf}^{sf} \text{ x } A^{sf}$
4. $A_l^{sf} = R_{lp}^{sf} \text{ x } A_{pf}^{sf}$
5. $N_l^{sf} = [(4 \text{ x } A_l^{sf})/(\pi \text{ x } (d_l^{sf})^2)]$
6. $y_l^{sf} = L^{sf}/N^{sf}$
7. $y_o^{sf} = R_{ol}^{sf} \text{ x } y_l^{sf}$
8. $A_o^{sf} = [(A_{pf}^{sf} \text{ x } y_o^{sf})/(N_l^{sf} \text{ x } W^{sf})]$
9. $d_o^{sf} = [4 \text{ x } A_o^{sf}/\pi]^{1/2}$
10. $A_m^{sf} = R_{ml}^{sf} \text{ x } A_l^{sf}$.
11. $d_m^{sf} = [4 \text{ x } A_m^{sf}/\pi]^{1/2}$
12. $D_t^{sf} = d_m^{sf} + D_g^{sf} + D_s^{sf} + F_b^{sf} + D_w^{sf}$.

UNITS

L^{sf}, m; W^{sf}, m; H^{sf}, m; d_l^{sf}, m; y_l^{sf}, m; y_o^{sf}, m; d_m^{sf}, m; A_o^{sf}, m^2; A_l^{sf}, m^2; A_{pf}^{sf}, m^2;

6.19 Design of Rapid Gravity Filter

1. Input: Average Flow, Q_a; Quantity of Backwash Water Used, Q_b^{rf}; Time Lost During Backwash, T_{lb}^{rf}; Design Rate of Filtration, R_f^{rf}; Length to Width Ratio of Filter, R_{lw}^{rf}; Diameter of Perforations, d_{pf}^{rf}; Free Board, F_b^{rf}; Effective Size of Sand, E_s^{rf}; Ratio of Area of Laterals to perforation, R_{lp}^{rf}; Ratio of Area of Manifold to Laterals, R_{ml}^{rf}; Maximum Size of Gravel, S_g^{rf}; Spacing of Laterals, y_l^{rf}; Wash-water Rate, R_{ww}^{rf}; Spacing of Troughs, y_{tr}^{rf}; Width of Trough, W_{tr}^{rf}
2. Put $N^{rf}=1$.
3. Compute Area of Filter, Length, Width and Depth. Use Equation Block 6-037.
4. If Area of Each Filter > 100 m^2, $N^{rf}=N^{rf}+1$. Go to 3.
5. Compute Number of Laterals, Diameter of Laterals, Area of Perforations, Total Number of Perforations, and their Distribution per Lateral and Diameter of Manifold. Use Equation Block 6-038.
6. Compute Dimension of Wash-water Trough and Overall Depth of Filter. Use Equation Block 6-039.
7. Display Design Flow Rate, Number of Filters, Length of Each Filter, Width of Each Filter, Sand Depth, Water Depth, Gravel Depth, Free Board, Overall Filter Depth, Diameter of Manifold, Total Number of Perforations, Diameter of Perforations, Number of Perforations per Lateral, Spacing of Perforations, Number of Wash-water Troughs, Depth and Width of Wash-water Trough.

DEFAULT VALUES

$Q_b^{rf} = 2\%$, $T_{lb}^{rf} = 30$ min, $R_f^{rf} = 5\ m^3/m^2/h$, $R_{lw}^{rf} = 1.3$, $d_{pf}^{rf} = 9$ mm, $F_b^{rf} = 0.3$ m, $E_s^{rf} = 0.6$ mm, $R_{lp}^{rf} = 3.0$, $R_{ml}^{rf} = 2.0$, $S_g^{rf} = 50$ mm, $y_l^{rf} = 15$ cm, $R_{ww}^{rf} = 36\ m^3/m^2/h$, $y_{tr}^{rf} = 1.6$ m, $W_{tr}^{rf} = 0.6$ m, $H_l^{rf} = 2.5$ m.

RANGE

$Q_b^{rf} = 2\text{-}4\%$, $T_{lb}^{rf} = 10\text{-}30$ min, $R_f^{rf} = 4.8\text{-}6.0\ m^3/m^2/h$, $R_{lw}^{rf} = 1.25\text{-}1.33$, $d_{pf}^{rf} = 5\text{-}12$ mm, $F_b^{rf} = 0.2\text{-}0.5$ m, $E_s^{rf} = 0.45\text{-}0.70$ mm, $R_{lp}^{rf} = 2.0\text{-}4.0$, $R_{ml}^{rf} = 1.5\text{-}2.0$, $S_g^{rf} = 40\text{-}50$ mm, $y_l^{rf} = 8\text{-}20$ cm, $R_{ww}^{rf} = 35\text{-}50\ m^3/m^2/h$, $y_{tr}^{rf} = 1.5\text{-}2.0$ m, $W_{tr}^{rf} = 0.5\text{-}1.0$ m, $H_l^{rf} = 1.0\text{-}4.5$ m.

EQUATION BLOCK 6-037

1. $Q_{ae}^{rf} = Q_a/N^{rf}$
2. $Q_d^{rf} = [Q_{ae}^{rf} \times (1 + Q_b^{rf}/100) \times 24/(24 - T_{lb}^{rf}/60)]$
3. $A^{rf} = [Q_d^{rf}/(R_f^{rf} \times 24)]$
4. $W^{rf} = [A^{rf}/R_{lw}^{rf}]^{1/2}$
5. $L^{rf} = W^{rf} \times R_{lw}^{rf}$

UNITS

Q_{ae}^{rf}, m^3/d; Q_d^{rf}, m^3/d; A^{rf}, m^2; W^{rf}, m; L^{rf}, m;

EQUATION BLOCK 6-038

1. $A_{pf}^{rf} = 0.003 \times A^{rf}$
2. $N_{pf}^{rf} = [A_{pf}^{rf} \times 4/(\pi \times (d_{pf}^{rf}/1000)^2)]$
3. $A_l^{rf} = R_{lp}^{rf} \times A_{pf}^{rf}$
4. $A_m^{rf} = R_{ml}^{rf} \times A_l^{rf}$
5. $d_m^{rf} = [A_m^{rf} \times 4/\pi]^{1/2}$
6. $N_l^{rf} = 2 \times L^{rf} \times 100/y_l^{rf}$
7. $A_{le}^{rf} = A_l^{rf}/N_l^{rf}$
8. $d_l^{rf} = [A_{le}^{rf} \times 4/\pi]^{1/2}$
9. $N_{pl}^{rf} = N_{pf}^{rf}/N_l^{rf}$
10. $L_l^{rf} = (W^{rf} - d_m^{rf}) \times 0.5$
11. $y_{pf}^{rf} = L_l^{rf} \times 100/N_{pl}^{rf}$

UNITS

A_{pf}^{rf}, m^2; A_l^{rf}, m^2; A_m^{rf}, m^2; d_m^{rf}, m; d_l^{rf}, m; y_{pf}^{rl}, m;

EQUATION BLOCK 6-039

1. $Q_{ww}^{rf} = R_{ww}^{rf} \times A^{rf} \times 24$
2. $N_{tr}^{rf} = W_{tr}^{rf}/y_{tr}^{rf}$
3. $Q_{tr}^{rf} = Q_{ww}^{rf}/N_{tr}^{rf}$
4. $D_{tr}^{rf} = [Q_{tr}^{rf}/(86400 \times W_{tr}^{rf})]^{2/3}$
5. $D_s^{rf} = [(R_f^{rf} \times 2 \times (d_s^{rf})^3 \times H_l^{rf})/(4 \times 10^{-4} \times 29323)]$
6. $D_g^{rf} = 2.54 \times 12 \times \log(S_g^{rf})/100$
7. $D_t^{rf} = d_m^{rf} + D_s^{rf} + D_g^{rf} + D_w^{rf} + F_b^{rf}$

UNITS

Q_{ww}^{rf}, m^3/d; Q_{tr}^{rf}, m^3/d; D_w^{rf}, m; D_s^{rf}, m; D_g^{rf}, m; D_t^{rf}, m; D_{tr}^{rf}, m;

6.20 Design of Lime-Soda Softening

1. Input: Average Flow, Q_a; Alkalinity, Al_k^{ls}; Calcium Hardness, h_{ca}^{ls}; Magnesium Hardness, h_{mg}^{ls}; Carbon Dioxide, h_c^{ls}; Effluent Hardness, h_e^{ls}.
2. Compute Fraction of Water to be Treated. Use Equation Block 6-040.
3. If 0.01<Fraction of Water < 1.0, Treatment Type = Split Treatment
   Fraction of Water<0.01, Treatment Type = Complete Treatment
4. Compute Lime Dose, Soda Dose, Additional Lime Dose for Mixed Flow, Additional Soda Dose for Mixed Flow, Total Soda Dose, Daily Lime Requirement and Daily Soda Requirement. Use Equation Block 6-041.
5. If Rapid Mix Design Required Then Design Rapid Mix Unit, Else Continue.
6. If Flocculation Unit Design Required then Design Flocculation Unit, Else Continue.
7. If Settling Unit Design Required then Design Settling Unit, Else Continue.
8. If Type of Treatment = Split Treatment, then Design Rapid Mix Unit and Settling Unit, Else Continue.
9. Display Flow Rate, Influent Water Parameters, Effluent Water Parameters, Lime Dose, Soda Dose, Additional Lime Dose, Additional Soda Dose, Total Lime Dose, Total Soda Dose, Daily Lime Requirement, Daily Soda Requirement, Design Details of Rapid Mix, Flocculation and Settling Units(If Selected).

DEFAULT VALUES

Al_k^{ls} = 300 mg/l, h_{mg}^{ls} = 100 mg/l as $CaCO_3$, h_{ca}^{ls} = 150 mg/l as $CaCO_3$, h_c^{ls} = 100 mg/l as $CaCO_3$, h_e^{ls} = 50 mg/l as $CaCO_3$.

RANGE

Al_k^{ls} = 300-1000 mg/l, h_{mg}^{ls} = 100-500 mg/l as $CaCO_3$, h_{ca}^{ls} = 150-200 mg/l as $CaCO_3$, h_c^{ls} = 100-500 mg/l as $CaCO_3$, h_e^{ls} = 30-50 mg/l as $CaCO_3$.

EQUATION BLOCK 6-040

1. $F_w^{ls} = [h_{mg}^{ls} - (h_e^{ls} - 35)/(h_{mg}^{ls} - 10)]$

EQUATION BLOCK 6-041

1. If $Al_k^{ls} > (h_{ca}^{ls} + h_{mg}^{ls})$

   $l_d^{ls} = h_c^{ls} + h_{ca}^{ls} + 2 \times h_{mg}^{ls} + [Al_k^{ls} - (h_{ca}^{ls} + h_{mg}^{ls})] + l_{ex}^{ls}$

   $S_d^{ls} = 0$

2. If $Al_k^{ls} < (h_{ca}^{ls} + h_{mg}^{ls})$ and $h_{ca}^{ls} > Al_k^{ls}$

   $l_d^{ls} = h_c^{ls} + Al_k^{ls} + h_{mg}^{ls} + l_{ex}^{ls}$

   $S_d^{ls} = (h_{ca}^{ls} - Al_k^{ls}) + h_{mg}^{ls}$

3. If $Al_k^{ls} < (h_{ca}^{ls} + h_{mg}^{ls})$ & $h_{ca}^{ls} < A_{lk}^{ls}$

   $l_d^{ls} = h_c^{ls} + h_{ca}^{ls} + 2 \times (Al_k^{ls} - h_{ca}^{ls}) + (h_{ca}^{ls} + h_{mg}^{ls} - Al_k^{ls})$

   $S_d^{ls} = [B_1 + B_2 + (1 - F_w^{ls}) \times h_{ca}^{ls})]/F_w^{ls}$

   Where F_w^{ls} = Fraction of Water to be Treated

   $B_1 = h_c^{ls}(1\text{-}F_w^{ls}) - 50 \times F_w^{ls}$

   $B_2 = [Al_k^{ls} - (h_{ca}^{ls} + h_{mg}^{ls}) \times (1 - F_w^{ls})$ If $Al_k^{ls} > (h_{ca}^{ls} + h_{mg}^{ls})$

   $B2 = 0$ If $Al_k^{ls} < (h_{ca}^{ls} + h_{mg}^{ls})$

4. $S_{de}^{ls} = (1 - F_w^{ls}) \times (h_{ca}^{ls} - Al_k^{ls})/F_w^{ls}$
5. $l_r^{ls} = 74 \times (F_w^{ls} \times Q_a \times l_d^{ls} + Q_a \times l_{ex}^{ls})/100$
6. $l_s^{ls} = 106 \times (F_w^{ls} \times Q_a \times S_d^{ls} + S_{de}^{ls} \times Q_a)/100$

UNITS

h_{ca}^{ls}, h_{mg}^{ls}, h_c^{ls}, h_c^{ls}, mg/l as $CaCO_3$; l_r^{ls}, kg/d; l_s^{ls}, kg/d;

6.21 Design of Ion Exchange Softening

1. Input: Average Flow, Q_a; Temperature, T_a; Total Influent Hardness as $CaCO_3$, h_i^{ie}; Service Flow Rate, v_{sr}^{ie}; Rinse Water Loading, v_{rw}^{ie}; Regeneration Interval, T_r^{ie}; Free Board, F_b^{ie}; Ratio of Length to Width of Brine Tank, R_{lwbr}^{ie}; Ratio of Width to Height of Brine Tank, R_{whbr}^{ie}; Ratio of Length to Width of Rinse Water Tank, R_{lwr}^{ie}; Ratio of Width to Height of Rinse Water Tank, R_{whr}^{ie}; Exchange Capacity of Resin, E_{cr}^{ie}; Common Salt value, C_{sv}^{ie}; % Solution of Brine, P_{br}^{ie}; Thickness Layer of Gravel, D_g^{ie}.
2. Put $N^{ie} = 1$.

3. Compute Flow Rate in Each Unit, Volume of Resin, Accumulated Hardness, Resin Bed Parameters(Diameter and Depth). Use Equation Block 6-042.
4. If $d_{rs}^{ie} > 5$ m, $N^{ie} = N^{ie} + 1$.
5. Compute Resin Bed Volume, Weight of Salt Required, Volume of Brine Water and Regeneration Time. Use Equation Block 6-043.
6. Compute Regeneration Flow Loading, Rinsing Discharge and Volume of Rinse Water. Use Equation Block 6-044.
7. Compute Brine Tank Parameters(Volume, Length, Width and Depth) and Rinsing Tank Parameters(Volume, Length, Width and Height). Use Equation Block 6-045.
8. Display Flow Rate, Exchange Capacity of Resin, Common Salt Value, Regeneration Time, Regeneration Interval, Volume of Resin, Resin Bed Parameters, Brine Tank Parameters, Free Board, Rinsing Tank Parameters, Volume of Brine, Volume of Rinse Water, Regeneration Flow Loading and Number of Units.

DEFAULT VALUES

$h_i^{ie} = 500$ mg/l as $CaCO_3$, $v_{sr}^{ie} = 0.25$ m/min, $v_{rw}^{ie} = 0.3$ m/min, $T_r^{ie} = 8$ h, $F_b^{ie} = 0.3$ m, $R_{lwbr}^{ie} = 1.0$, $R_{wdbr}^{ie} = 1.0$, $R_{lwr}^{ie} = 1.0$, $R_{whr}^{ie} = 1.0$, $E_{cr}^{ie} = 10$ kg/m^3, $C_{sv}^{ie} = 5.0$, $P_{br}^{ie} = 10$, $D_g^{ie} = 0.4$ m.

RANGE

$h_i^{ie} = 500\text{-}2000$ mg/l as $CaCO_3$, $v_{sr}^{ie} = 0.15\text{-}0.30$ m/min, $v_{rw}^{ie} = 0.2\text{-}0.3$ m/min, $T_r^{ie} = 8\text{-}12$ h, $F_b^{ie} = 0.3\text{-}0.5$ m, $R_{lwbr}^{ie} = 1.0\text{-}3.0$, $R_{wdbr}^{ie} = 1.0\text{-}3.0$, $R_{lwr}^{ie} = 1.0\text{-}3.0$, $R_{whr}^{ie} = 1.0\text{-}3.0$, $E_{cr}^{ie} = 7\text{-}14$ kg/m^3, $C_{sv}^{ie} = 3.5\text{-}7.0$, $P_{br}^{ie} = 10\text{-}15$, $D_g^{ie} = 0.35\text{-}0:45$ m.

EQUATION BLOCK 6-042

1. $Q_{ac}^{ie} = Q_a/N^{ie}$
2. $h_a^{ie} = T_r^{ie} \text{ x } 3600 \text{ x } Q_{ac}^{ie} \text{ x } h_i^{ie}/(86400 \text{ x } 1000)$
3. $V_{rs}^{ie} = h_a^{ie}/E_{cr}^{ie}$
4. $A_{rs}^{ie} = [Q_{ac}^{ie}/(v_{sr}^{ie} \text{ x } 1440)]$
5. $d_{rs}^{ie} = [4 \text{ x } A_{rs}^{ie}/\pi]^{1/2}$
6. $D_{rs}^{ie} = V_{rs}^{ie}/A_{rs}^{ie}$

UNITS

Q_{ac}^{ie}, m^3/d; h_a^{ie}, kg; V_{rs}^{ie}, m^3; A_{rs}^{ie}, m^2; d_{rs}^{ie}, m; D_{rs}^{ie}, m; h_i^{ie}, mg/l

EQUATION BLOCK 6-043

1. $w_s^{ie} = h_a^{ie}/C_{sv}^{ie}$
2. $V_{brw}^{ie} = [w_s^{ie}/(P_{br}^{ie} \times 10)]$
3. $T_{rt}^{ie} = [V_{brw}^{ie}/(0.15 \times V_{rs}^{ie})]$

    If $T_{rt}^{ie} < 1800$ s, $T_{rt}^{ie} = 1800$ s

    If $T_{rt}^{ie} > 2700$ s, $T_{rt}^{ie} = 2700$ s

UNITS

w_s^{ie}, kg/d; V_{brw}^{ie}, m^3/d;

EQUATION BLOCK 6-044

1. $Q_{rf}^{ie} = V_{brw}^{ie}/T_{rt}^{ie}$
2. $Q_{rw}^{ie} = v_{rw}^{ie} \times A_{rs}^{ie}/60$
3. $V_{rw}^{ie} = Q_{rw}^{ie} \times T_{rs}^{ie}$ If

    $V_{rw}^{ie} > 10 \times V_{rs}^{ie}$

    $V_{rw}^{ie} = 10 \times V_{rs}^{ie}$

    If $V_{rw}^{ie} < 3 \times V_{rs}^{ie}$

    $V_{rw}^{ie} = 3 \times V_{rs}^{ie}$

UNITS

Q_{rf}^{ie}, m^3/s; Q_{rw}^{ie}, m^3/s; V_{rw}^{ie}, m^3; v_{rw}, m/min, T_{rs}, sec.

EQUATION BLOCK 6-045

1. $V_{br}^{ie} = V_{brw}^{ie} \times (24/T_r^{ie}$ or 3, Whichever is Less)
2. $L_{br}^{ie} = [(R_{lwbr}^{ie})^2 \times R_{wdbr}^{ie} \times V_{br}^{ie}]^{1/3}$
3. $W_{br}^{ie} = L_{br}^{ie}/R_{lwbr}^{ie}$
4. $D_{br}^{ie} = W_{br}^{ie}/R_{wdbr}^{ie}$
5. $V_{rs}^{ie} = 6 \times V_{rw}^{ie}$
6. $L_{rs}^{ie} = [(R_{lwr}^{ie})^2 \times R_{wdr}^{ie} \times V_{rs}^{ie}]^{1/3}$
7. $W_{rs}^{ie} = L_{rs}^{ie}/R_{lwr}^{ie}$
8. $D_{rs}^{ie} = W_{rs}^{ie}/R_{wdr}^{ie}$

UNITS

V_{br}^{ie}, m^3; L_{br}^{ie}, m; W_{br}^{ie}, m; D_{br}^{ie}, m; V_{rs}^{ie}, m^3; L_{rs}^{ie}, m; W_{rs}^{ie}, m; D_{rs}^{ie}, m;

6.22 Design of Pre-chlorination Facility

1. Input: Average Flow, Q_a; Contact Period, T_c^{prc}; Hydrogen Sulfide Concentration, C_h^{prc}; Iron Concentration, C_{ir}^{prc}; Manganese Concentration, C_{mn}^{prc}; Ammonia Concentration, C_a^{prc}; Length to Width Ratio of Chlorinating Tank, R_{lw}^{prc}; Width to Height Ratio of Chlorinating Tank, R_{wh}^{prc}; Number of End baffles, N_b^{prc}.
2. Put $N^{prc} = 1$
3. Input: Width of Submerged Opening, W_o^{prc}; Width of Influent Chamber, W_{ic}^{prc}; Height of Submerged Opening, H_o^{prc}; Height of Weir Crest Above the Bottom, H_{wb}^{prc}.
4. Compute Optimum Chlorine Dose, Additional Chlorine Dose and Daily Disinfectant Requirement. Use equation Block 6-046.
5. Compute Tank Parameters(Length, Width and Height), Channel Parameters(Length, Width and Number) and Baffle Parameters(Length and Height). Use Equation Block 6-047.
6. Display Flow Rate, Contact Period, Name of Disinfectant, Total Chlorine Dose, Daily Disinfectant Requirement, Tank Parameters, Channel Parameters and Baffle Parameters.

DEFAULT VALUES

$T_c^{prc} = 30$ min, $C_h^{prc} = 0$, $C_{ir}^{prc} = 0$, $C_{mn}^{prc} = 0$, $C_a^{prc} = 0$, $R_{lw}^{prc} = 4.0$, $R_{wh}^{prc} = 2.0$

RANGE

$T_c^{prc} = 20\text{-}30$ min, $C_h^{prc} = 0\text{-}5$ mg/l, $C_{ir}^{prc} = 0\text{-}5$ mg/l, $C_{mn}^{prc} = 0\text{-}5$ mg/l, $C_a^{prc} = 0\text{-}5$ mg/l, $R_{lw}^{prc} = 4.0\text{-}10.0$, $R_{wh}^{prc} = 2.0\text{-}4.0$

EQUATION BLOCK 6-046

1. $C_{op}^{prc} = [3600 \times k/T_c^{prc}]^{1/n}$

   $k = \text{Constant} = 26$

   $n = \text{Constant} = 0.87$
2. $cl_a^{prc} = 2.1 \times C_h^{prc} + 0.63 \times C_{ir}^{prc} + 1.3 \times C_{mn}^{prc} + 10 \times C_a^{prc}$
3. $cl_t^{prc} = 8.21 \times 10^{-8} \times C_{op}^{prc} + cl_a^{prc}$

4 $cl_d^{prc} = cl_t^{prc}/x$

x	Disinfectant
1.0	Chlorine
0.36	Bleaching Powder
0.72	Calcium Hypochlorite
0.14	Sodium Hypochlorite
2.63	Chlorine Dioxide
1.38	Monochloroamine
1.65	Dichloroamine
1.77	Trichloroamine

4. $cl_r^{prc} = Q_{ae} \times cl_d^{prc}$

UNITS

C_{op}^{prc}, lb/MG; cl_t^{prc}, kg/m^3; cl_a^{prc}, g/l; cl_r^{prc}, kg/d;

EQUATION BLOCK 6-047

1. $Q_{ae}^{prc} = Q_a/N^{prc}$
2. $V^{prc} = Q_{ae}^{prc} \times T_c^{prc}/1440$
3. $L^{prc} = [V^{prc} \times ((R_{lw}^{prc})^2 \times (R_{wh}^{prc}))]^{1/3}$
4. $W^{prc} = L^{prc}/R_{lw}^{prc}$
5. $H^{prc} = W^{prc}/R_{wh}^{prc}$
6. $W_{ch}^{prc} = H^{prc}/R_{hw}^{prc}$
7. $L_{ch}^{prc} = W^{prc}$
8. $N_{ch}^{prc} = L^{prc}/W_{ch}^{prc}$
9. $L_b^{prc} = W^{prc} - W_{ch}^{prc}$
10. $H_b^{prc} = H^{prc}$
11. $H_l^{prc} = [(pf \times Q_a)/(86400 \times 0.61 \times (2g)^{0.5} \times W_0^{prc} \times H_o^{prc})]^2$
12. $H_w^{prc} = D_{ch}^{prc} - H_{wb}^{prc}$
13. $L_{wt}^{prc} = [Q_{ae}^{prc}/(86400 \times 1.57 \times 0.6 \times (2g)^{1/2} \times (H_w^{prc})^{3/2})]$
14. $L_c^{prc} = L_{wt}^{prc} \times (H_w^{prc})^{1/2}/(0.02)^{1/2}$
15. $H_a^{prc} = [Q_{ae}/(86400 \times 1.57 \times 0.6 \times (2g)^{1/2} \times L_{wt}^{prc})]^{2/3}$

V^{prc}, m^3; L^{prc}, m; W^{prc}, m; H^{prc}, m; W_{ch}^{prc}, m; L_{ch}^{prc}, m; L_b^{prc}, m; H_b^{prc}, m; H_l^{prc}, m; H_w^{prc}, m; L_{wt}^{prc}, m; L_c^{prc}, m;

6.23 Design of Post-chlorination Facility

1. Input: Average Flow, Q_a; Contact Period, T_c^{poc}; Length to Width Ratio of Chlorinating Tank, R_{lw}^{poc}; Width to Height Ratio of Chlorinating Tank, R_{wh}^{poc}; Number of End baffles, N_b^{poc}.
2. Put $N^{poc} = 1$
3. Input: Width of Submerged Opening, W_o^{poc}; Width of Influent Chamber, W_{ic}^{poc}; Height of Submerged Opening, H_o^{poc}; Height of Weir Crest Above the Bottom, H_{wb}^{poc}.
4. Compute Optimum Chlorine Dose, Additional Chlorine Dose and Daily Disinfectant Requirement. Use Equation Block 6-048.
5. Compute Tank Parameters(Length, Width and Height), Channel Parameters(Length, Width and Number) and Baffle Parameters(Length and Height). Use Equation Block 6-049.
6. Display Flow Rate, Contact Period, Name of Disinfectant, Total Chlorine Dose, Daily Disinfectant Requirement, Tank Parameters, Channel Parameters and Baffle Parameters.

DEFAULT VALUES

$T_c^{poc} = 30$ min, $R_{lw}^{poc} = 4.0$, $R_{wh}^{poc} = 2.0$

RANGE

$T_c^{poc} = 20\text{-}30$ min, $R_{lw}^{poc} = 4.0\text{-}10.0$, $R_{wh}^{poc} = 2.0\text{-}4.0$

EQUATION BLOCK 6-048

1. $C_{op}^{poc} = [3600 \times k/T_c^{poc}]^{1/n}$

   k = Constant = 26

   n = Constant = 0.87

2. $C_{lt}^{prc} = 8.21 \times 10^{-8} \times C_{op}^{poc}$
3. $Cl_d^{poc} = Cl_t^{poc}/x$

x	Disinfectant
1.0	Chlorine

0.36	Bleaching Powder
0.72	Calcium Hypochlorite
0.14	Sodium Hypochlorite
2.63	Chlorine Dioxide
1.38	Monochloroamine
1.65	Dichloroamine
1.77	Trichloroamine

4. $Cl_t^{poc} = Q_{ae} \times Cl_d^{poc}$

UNITS

C_{op}^{poc}, lb/MG; Cl_t^{poc}, kg/m^3; Cl_r^{poc}, kg/d;

EQUATION BLOCK 6-049

1. $Q_{ae}^{poc} = Q_a/N^{poc}$
2. $V^{poc} = Q_{ae}^{poc} \times T_c^{poc}/1440$
3. $L^{poc} = [V^{poc}/((R_{lw}^{poc})^2 \times (R_{wh}^{poc}))]^{1/3}$
4. $W^{poc} = L^{poc}/R_{lw}^{poc}$
5. $H^{poc} = W^{poc}/R_{wh}^{poc}$
6. $W_{ch}^{poc} = H^{poc}/R_{hw}^{poc}$
7. $L_{ch}^{poc} = W^{poc}$
8. $N_{ch}^{poc} = L^{poc}/W_{ch}^{poc}$
9. $L_b^{poc} = W^{poc} - W_{ch}^{poc}$
10. $H_b^{poc} = H^{poc}$
11. $H_l^{poc} = [(pf \times Q_a)/(86400 \times 0.61 \times (2g)^{0.5} \times W_o^{poc} \times H_o^{poc})]^2$
12. $H_w^{poc} = D_{ch}^{poc} - H_{wb}^{poc}$
13. $L_{wt}^{poc} = [Q_{ae}^{poc}/(86400 \times 1.57 \times 0.6 \times (2g)^{1/2} \times (H_w^{poc})^{3/2})]$
14. $L_c^{poc} = L_{wt}^{poc} \times (H_w^{poc})^{1/2}/(0.02)^{1/2}$
15. $H_a^{poc} = [Q_{ae}/(86400 \times 1.57 \times 0.6 \times (2g)^{1/2} \times L_{wt}^{poc})]^{2/3}$

UNITS

V^{poc}, m^3; L^{poc}, m; W^{poc}, m; H^{poc}, m; W_{ch}^{poc}, m; L_{ch}^{poc}, m; L_b^{poc}, m; H_b^{poc}, m; H_l^{poc}, m; H_w^{poc}, m; L_{wt}^{poc}, m; L_c^{poc}, m;

7 Design Methodologies – III: Wastewater Treatment

The basic aim of wastewater treatment is to remove the impurities (organic and inorganic matter) for safe disposal of water. To formulate the design approach, Manual on Sewerage and Sewage Treatment has been consulted. But in case of some unit operations that have not been dealt in detail in the manual, but are quite frequent in use, several standard text books and journals have been consulted to formulate their design approach. Fair *et al.* (1968), Bhole (1975), Patwardhan (1977), USEPA (1977), Hammer (1977), Arceivala (1981), Benefield *et al.* (1984), Quasim (1985), Peavy *et al.* (1987), Davis and Cornell (1991), Haandel and Lettinga (1994) and Metcalf (1997), etc. have been consulted besides manual to formulate the design approach and provide a recommended range in which the option functions efficiently.

7.1 Design of Bar Screens

1. Input: Average Flow Q_a^b; Peaking Factor pf; Flow Velocity through Racks V_f^b; Depth of Flow D_f^b; Spacing of Bars y_b^b; Width of Bars W_b^b; Coefficient of Expansion K_e; Slope of Bars α^b; Amount of Screen S_c^b.
2. Put Number of Units $N^b = 1$
3. Compute Clear Area, Spacing, and Efficiency of the Bar Racks. Use Equation Block 7-001.
4. Compute Actual Depth and Velocity of Flow Through Bar Racks. Use Equation Block 7-002.

5. Compute Head Loss at Clear and 50% Clogging Conditions Through Bar Racks and Quantity of Screen. Use Equation Block 7-003.
6. Display Flow, Number of Units, Spacing of Bars, Width of Bar, Efficiency Coefficient, Head Loss at Different Conditions and Amount of Screen.

DEFAULT VALUES

$v_f^b = 0.9$ m/s, $D_f^b = 1.0$ m, $y_b^b = 25$mm, $W_b^b = 8$mm, $K_e = 0.30$, $\alpha^b = 75^0$, $S^b = 0.015$ m^3/ML

RANGE

$v_f^b = 0.6 - 1.0$ m/s, $D_f^b = 0.5 - 0.75$ m, $y_b^b = 10 - 50$ mm, $W_b^b = 8 - 10$ mm, $\alpha^b = 75 - 85^0$, $S^b = 0.0015 - 0.015$ m^3/ML

EQUATION BLOCK 7-001

1 $Q_{pe}^b = Q_a \times pf/N^b$

2. $A_n^b = 1.157 \times 10^{-5} \times Q_{pe}^b/V_f^b$

3. $W_c^b = A_n^b/D_f^b$

4 $N_c^b = 10^3 \times W_c^b/y_b^b$

5. $W_t^b = 10^{-3} \times [N_c^b \times y_b^b + W_b^b \times (N_c^b - 1)]$

6. $\eta^b = W_c^b/W_t^b$

UNITS

Q_{pe}^b, m^3/d; A_n^b, m^2; W_c^b, m; W_t^b, m;

EQUATION BLOCK 7-002

1. Actual Depth of Flow at the Upstream can be Evaluated from the Following Expression

$Z^b + D_f^b + 0.051 \times (V_f^b)^2 = D_a^b + 0.051 \times (Q_{pe}^b/(W_t^b \times D_a^b \times 86400))^2 + 0.051 \times K_e \times [(V_f^b)^2 - (Q_{pe}^b/(W_t^b \times D_a^b \times 86400))^2]$

2. $V_{af}^b = [Q_{pe}^b/(W_n^b \times D_a^b \times 86400)]$

If This Velocity Differs the Initial Assumed Velocity by 5%, Start Blinking.

UNITS

D_a^b, m; V_{af}^b, m/s; Z^b, m;

EQUATION BLOCK 7-003

1. $H_a^b = 0.0729 \times [(v_{at}^b)^2 \quad (Q_{pe}^b/(W_t^b \times D_a^b \times 86400))^2]$
2. $H_{50}^b = 0.0729 \times [(2 \times v_{at}^b)^2 \quad (Q_{pe}^b/(W_t^b \times D_a^b \times 86400))^2]$
3. $C^b = 0.001 \times S^b \times Q_{pe}^b$

UNITS

H_a^b, m; H_{50}^b, m; C^b, m^3/d;

7.2 Proportionate Flow Grit Chamber

1. Input :Average Flow, Q_a; Particle Size, d_p; Specific Gravity, G_s; Peak Factor, pf; Ratio of Length to Width, R_{lw}^P; Efficiency of Removal, η; Grit Content, g_c^P; Free Board, F_b^P; Weir Dimension 'a', Performance Factor, P_f, Grit Storage Space, g_s^P.
2. Put $N^P = 1.0$.
3. Compute Surface Overflow Rate, Length, Width, Depth and HRT in Tank. Use Equation Block 7-004.
4. Compute the Details of Proportionate Flow Weir and Amount of Grit. Use Equation Block 7-005.
5. Display Flow, Number of Units, Length, Width, Depth, Amount of Grit and Details of Proportionate Flow Weir.

DEFAULT VALUES

$d_p = 0.00015$ m, $G_s = 2.65$, $R_{lw}^P = 2.0$, $\eta = 0.75$, $g_c^P = 30\ m^3/10^6\ m^3$, $F_b^P = 0.3$ m, pf = 2.25; Weir Dimension a = 30 mm, $P_f = 0.125$, $g_s^P = 0.3$ m.

RANGE

$d_p = 0.00015$-0.0025 m, $R_{lw}^P = 2.0$-8.0, $\eta = 0.75$-1.0, $g_c^P = 5$-$200\ m^3/10^6\ m^3$, $F_b^P = 0.3$-0.5 m, Weir Dimension a = 25-50 mm, $P_f = 0.125$-1.0, $g_s^P = 0.3$ m.

7.3 Design of Parshall Flume Grit Chamber

1. Input: Average Flow, Q_a; Peaking Factor, pf; Minimising Factor, mf; Throat Width, W_{th}^{pa}; Depth of Flow, D_f^{pa}; Velocity of Flow, v_f^{pa}; Hydraulic Retention Time, hrt^{pa}.
2. Compute Depth of Flow in the Upstream Leg of the Flume and Z. Use Equation Block 7-006.

EQUATION BLOCK 7-004

1. $Q_{pe}^{p} = pf \times Q_a/N^{p}$
2. $v_{st}^{p} = [g \times (G_s - 1) \times (d_p)^2/(\upsilon_l \times 18)]$
3. $R_e = v_{st}^{p} \times d_p/\upsilon_l$

   If $R_e < 0.5$

   $v_{st}^{p} = v_{st}^{p}$ Calculated in (2)

   Else if $0.5 < R_e < 1000$

   $v_{st}^{p} = [0.707 \times (G_s - 1) \times (d_p)^{1.6} \times (\upsilon_l)^{-0.6}]^{0.714}$

   Else

   $v_{st}^{p} = [3.3 \times g \times (G_s - 1) \times d_p]^{0.5}$
4. $sor^{p} = v_{st}^{p}/[(1/P_f) \times ((1 - \eta)^{-P_f} - 1)]$
5. $A^{p} = Q_{pe}^{p}/(86400 \times sor^{p})$
6. $W^{p} = [A^{p}/R_{lw}^{p}]^{1/2}$
7. $L^{p} = W^{p} \times R_{lw}^{p}$
8. $v_{sc}^{p} = 3$ to $4.5 \times [g \times (G_s - 1) \times d_p]^{1/2}$
9. $D^{p} = [Q_{pe}^{p}/(v_{sc}^{p} \times W^{p} \times 86400)]$
10. $hrt^{p} = L^{p} \times W^{p} \times D^{p} \times 1440/Q_{pe}^{p}$
11. $g_t^{p} = g_c^{p} \times Q_{pe}^{p}/10^6$
12. $D_t^{p} = D^{p} + g_s^{p} + F_b^{p}$

UNITS

Q^{pe}, m^3/d; v_{st}^{p}, m/s; sor^{p}, m/s; L^{p}, m; W^{p}, m; D^{p}, m; v_{sc}^{p}, m/s; g_t^{p}, m^3/d, D_t^{p}, m.

EQUATION BLOCK 7-005

1. $b^{p} = [Q_{pe}^{p}/(86400 \times 0.61 \times (2 \times 10^{-3} \times a \times g)^{1/2} \times (D^{p} - (a \times 10^{-3})/3))]$
2. To Determine the Coordinates (x,y) of the Curve Forming the Edge of the Weir, Assume Suitable Values of y and Compute Corresponding Values of x Using Equation $x = b/2 \times [1 - (2/\pi) \times \tan^{-1}((y \times 10^3)/a - 1)^{1/2}]$

UNITS

b, m; x, m; y, m;

3. Compute Depth of Flow at Various Flow Conditions, Width of Flume, Average Velocity of Flow and Length of Flume. Use Equation Block 7-007.

4. Display Flow, Peaking Factor, Number of Units, Throat Width, Depth of Chamber, and Length of Chamber.

DEFAULT VALUES

$pf = 2.25$, $mf = 0.33$, $W_{th}^{pa} = 0.075$ m, $v_f^{pa} = 0.3$ m/min, $hrt^{pa} = 1$ min

RANGE

$W_{th}^{pa} = 0.075\text{-}2.4$ m, $v_f^{pa} = 0.3\text{-}0.6$ m/min, $hrt^{pa} = 1 - 2$ min.

EQUATION BLOCK 7-006

1. $Q_{ae}^{pa} = Q_a/N^{pa}$
2. $Q_{pe}^{pa} = pf \times Q_a/N^{pa}$
3. $Q_{mn}^{pa} = mf \times Q_a/N^{pa}$
4. $D_{fu}^{pa} = [(Q_{ae}^{pa} \times 1000)/(2264 \times W_{th}^{pa} \times 86400)]^{2/3}$
5. $Z = (D_{mn}^{pa}/D_{mx}^{pa}) = (Q_{mn}^{pa}/Q_{pe}^{pa}) = [\{1.1 \times Q_{mn}^{pa} \times 1000/(2264 \times W_{th}^{pa} \times 86400)\}^{2/3} - Z]/[\{1.1 \times Q_{pe}^{pa} \times 1000/(2264 \times W_{th}^{pa} \times 86400)\}^{2/3} - Z]$

UNITS

Q_{ae}^{pa}, m^3/d; Q_{mn}^{pa}, m^3/d; Q_{pe}^{pa}, m^3/d; D_{fu}^{pa}, m;

EQUATION BLOCK 7-007

1. $D_{fa}^{pa} = 1.1[(Q_{ae}^{pa} \times 1000)/2264 \times W_{th}^{pa} \times 86400]^{2/3} - Z$
2. $D_{fmn}^{pa} = 1.1[(Q_{mn}^{pa} \times 1000)/2264 \times W_{th}^{pa} \times 86400]^{2/3} - Z$
3. $D_{fmx}^{pa} = 1.1[(Q_{pe}^{pa} \times 1000)/2264 \times W_{th}^{pa} \times 86400]^{2/3} - Z$
4. $W^{pa} = [(Q_{pe}^{pa} \times 1000)/(86400 \times D_{fmx}^{pa} \times v_f^{pa})]$
5. $v_{af}^{pa} = [(Q_{ae}^{pa} \times 1000)/(86400 \times W^{pa} \times D_{fa}^{pa})]$
6. $L^{pa} = [(Q_{ae}^{pa} \times hrt^{pa})/(1440 \times W_{th}^{pa} \times D_{fa}^{pa})]$

UNIT

W^{pa}, m; L^{pa}, m; D_{fa}^{pa}, m; D_{fmn}^{pa}, m; D_{fmx}^{pa}, m; v_{af}^{pa}, m/s;

7.4 Design of Aerated Grit Chamber

1. Input. Average Flow, Q_a; Peaking Factor, pf; Specific Gravity of Particles, G_s; Diameter of Particles, d_p; Kinematic Viscosity, υ_l; Grit Storage Space, g_s^{ag}; Free-board, F_b^{ag}; Air Requirement per Unit Length, A_{al}^{ag}; Spacing of Pipes, y_p^{ag}; Spacing of Nozzles, y_{nh}^{ag}; Atmospheric Pressure, p; Ratio of Length to Width, R_{lw}^{ag}.
2. Put $N^{ag} = 1$
3. Compute Surface Overflow Rate and Tank Parameters (Length, Width and Depth). Use Equation Block 7-008.
4. If Length of Grit Chamber > 20 m, Put $N^{ag} = N^{ag} + 1$
5. Compute Air Requirement, Blower Capacity, Number of Nozzles, Grit Content. Use Equation Block 7-009.
6. Display Design Flow, Length, Width, Total Depth, Grit Content, Air Required, Blower Capacity, Number of Pipes and Nozzles, Spacing of Pipes and Nozzles and Hydraulic Retention Time.

DEFAULT VALUES

pf = 2.25, $G_s = 2.65$, $d_p = 0.15$ mm, $\upsilon_l = 1.01 \times 10^{-6}$ m²/sec $g_s^{ag} = 0.25$ m, $F_b^{ag} = 0.3$ m, $P_f = 0.125$, $\eta^{ag} = 0.75$, $A_{al}^{ag} = 7.8$ l/s-m, $y_p^{ag} = 0.3$ m, $y_{nh}^{ag} = 0.2$ m, $g_c^{ag} = 30\ m^3/10^6 m^3$, $R_{lw}^{ag} = 4.0$.

RANGE

$d_p = 0.15\text{-}1.5$ mm, $g_s^{ag} = 0.25\text{-}0.50$ m, $F_b^{ag} = 0.3\text{-}0.5$ m, $P_f = 0.125\text{-}1.0$, $\eta^{ag} = 0.75\text{-}1.0$, $A_{al}^{ag} = 7.0\text{-}15.0$ l-s/m, $y_p^{ag} = 0.2\text{-}0.5$ m, $y_{nh}^{ag} = 0.2\text{-}0.5$ m, $g_c^{ag} = 5\text{-}200\ m^3/10^6 m^3$, $R_{lw}^{ag} = 3.0\text{-}5.0$

7.5 Design of Skimming Tank

1. Input: Average Flow, Q_a; Rise velocity, v_r^s; Ratio of Length to Width, R_{lw}^s; Depth, D^s; Air Required per m³ of Sewage, A_{as}^s; Spacing of Diffuser Pipes, y_p^s; Spacing of Nozzles, y_{nh}^s.

EQUATION BLOCK 7-008

1. Q_{pe}^{ag} Q_{ae}^{ag} x pf/N^{ag}

2. $v_{st}^{ag} = [g \times (G_s-1) \times (d_p)^2/18\upsilon_l] \times 10^{-6}$

3. $R_e = [v_{st}^{ag} \times d_p/\upsilon_l] \times 10^{-3}$

4. If $R_e <= 0.5$

   v_{st}^{ag} v_{st}^{ag} as Calculated Above

If $0.5 <= R_e <= 1000$

   Settling Velocity $v_{st}^{ag} = [0.707 \times (G_s-1)(d_p \times 10^{-3})^{1.6}(\upsilon_l)^{-0.6}]$

If $R_e >= 1000$

   Settling Velocity $v_{st}^{ag} = [3.3 \times g \times (G_s-1) \times d_p \times 10^{-3}]^{0.5}$

5. $sor^{ag} = [(v_{st}^{ag} \times P_l/1-\eta)^{-P_f} - 1]$

6. $A^{ag} = [Q_{pe}^{ag}/(86400 \times sor^{ag})]$

7. $W^{ag} = [A^{ag}/R_{lw}^{ag}]^{1/2}$

8. $L^{ag} = R_{lw}^{ag} \times W^{ag}$

9. $v_{sc}^{ag} = K[(G_s-1) \times g \times d_p]^{0.5}$

10. $D^{ag} = [Q_{pe}^{ag}/(v_{sc}^{ag} \times W^{ag} \times 86400)]$

11. $hrt^{ag} = [(D^{ag} \times L^{ag} \times W^{ag} \times 1440)/Q_{pe}^{ag}]$

12. $D_t^{ag} = D^{ag} + g_s^{ag} + F_b^{ag}$

13. $g_t^{ag} = [(g_c^{ag} \times Q_{ae}^{ag})/10^6]$

UNITS

Q_{pe}^{ag}, m^3/d; L^{ag}, m; W^{ag}, m; D^{ag}, m; v_{sc}^{ag}, m; g_t^{ag}, m^3/d;

2. Compute Area, Length, Width, Depth, Air Required, Hydraulic Retention Period, Blower Capacity, Spacing and Number of Nozzles, Spacing and Number of Pipes. Use Equation Block 7-010.
3. Display Design Flow, Number of Skimmers, Length, Width, Depth and Hydraulic Retention Period of Skimming Tank, Air Required, Number and Spacing of Pipes, Number and Spacing of Nozzles.

EQUATION BLOCK 7-009

1. $A_r^{ag} = 1.5 \times A_{al}^{ag} \times L^{ag}$
2. $B_c^{ag} = [A_r^{ag} \times 6 \times 10^{-2}]$
3. $N_p^{ag} = \text{Int}(W^{ag}/y_p^{ag})$
4. $Y_{ap}^{ag} = W^{ag}/N_p^{ag}$
5. $N_{np}^{ag} = \text{Int}[(L^{ag} - y_p^{ag})/y_{nh}^{ag}]$
6. $y_{an}^{ag} = [(L^{ag} - y_{ap}^{ag})/N_{np}^{ag}]$
7. $N_n^{ag} = N_p^{ag} \times N_{np}^{ag}$
8. $Bhp = [(1.201 \times A_r^{ag} \times 8.314)/(8.41 \times 0.7)]\,(T_a+273)\,[(p/(0.95 \times 760)]^{0.283} - 1]$

UNITS

y_{an}^{ag}, m; y_p^{ag}, m; A_r^{ag}, m^3/min; bhp, hp;

DEFAULT VALUES

$v_r^s = 0.25$ m/min, $D^s = 1.0$ m, $R_{lw}^s = 6.0$, $y_p^s = 0.3$ m, $y_{nh}^s = 0.2$ m.

RANGE

$v_r^s = 0.20\text{-}1.0$ m/min, $D_s = 1.0\text{-}2.0$ m, $R_{lw}^s = 3.0\text{-}6.0$, $y_p^s = 0.2\text{-}1.0$ m, $y_{nh}^s = 0.2\text{-}1.0$ m.

EQUATION BLOCK 7-010

1. $A^s = 0.00622 \times Q_a/v_r^s$
2. $W^s = [A^s/R_{lw}^s]^{1/2}$
3. $L^s = W^s \times R_{lw}^s$
4. $hrt^s = (A^s \times D^s \times 1440)/Q_a$
5. $A_r^s = A_{as}^s \times Q_a/1440$
6. $B_c^s = A_r s \times 60/1000$
7. $N_p^s = W^s/y_p^s$
8. $N_{np}^s = [L^s - y_p^s]/y_n^s$
9. $N_{nt}^s = N_p^s \times N_{np}^s$

UNITS

A^s, m^2; W^s, m; L^s, m; hrt^s, min;

7.6 Design of Equalization Chamber

1. Input: Time Interval of Flow Data, T_d^c; Flow Corresponding to Each Time Interval, Q_i^c; Depth of Equalization Chamber, D^c;
2. Put $N^c = 1$.
3. Compute Volume, Depth and Diameter or Length and Width of Equalization Chamber. Use Equation Block 7-011.
4. If Diameter of Equalization Chamber Exceeds 60 m or Length > 90 m; Put $N^c = N^c + 1$.
5. Display Average Flow, Volume of Equalization Chamber, Diameter of Equalization Chamber(Circular) or Length and Width of Clarifier(Rectangular)

DEFAULT VALUES

$T_d^c = 1$ h, $D^c = 2.0$ m .

EQUATION BLOCK 7-011

1. $N_d^c = 24/T_d^c$
2. Read Flow Rate Corresponding to Each Time Interval.
3. $Q_t^c = \Sigma Q_i^c$
4. $Q^a = Q_t^c/N_d^c$
5. $V^c = \Sigma(Q_i^c - Q_a) \times T_d^c/24$ When $Q_i^c > Q_a$
6. $V_d^c = 1.2 \times V^c$
7. $V_e^c = Q_d^c/N^c$
8. $A^c = V_e^c / D^c$
9. If Chamber is Circular, $d^c = [4 \times A^c/\pi]^{1/2}$
10. If Chamber is Rectangular, $W^c = [A^c/R_{lw}^c]^{1/2}$
11. $L^c = R_{lw}^c \times W^c$.

UNITS

Q_i, m^3/d, V^c, m^3; V_e^c, m^3; L^c, m; W^c, m; D^c, m;

7.7 Design of Diffused Aeration Process

Please refer to section 6.1.

7.8 Design of Cascade Aeration

Please refer to section 6.2.

7.9 Design of Spray Aeration System

Please refer to section 6.3.

7.10 Design of Primary Rectangular Clarifier.

Please refer to section 6.6.

7.11 Design of Primary Circular Radial Flow Clarifier

Please refer to section 6.7.

7.12 Design of Primary Circumferential Flow Circular Clarifier

Please refer to section 6.8.

7.13 Design of Activated Sludge Process

1. Input: Average Flow, Q_a; MLSS, X_s^{asp}; Mean Cell Residence Time, $bsrt^{asp}$; Yield Coefficient, y_t^{asp}; k_d, Influent BOD Concentration, S_0; Effluent BOD Concentration, S_e; Sludge Volume Index(SVI), svi^{asp}; Peaking Factor, pf; Nitrogen Content, N_t^{asp}; Phosphorous Content, P_c^{asp}.
2. Put $N^{asp} = 1$
3. Compute Volume, Length, Width, and Depth of the Aeration Tank. Use Equation Block 7-012.
4. If Length > 100 m, Put $N^{asp} = N^{asp} + 1$
5. Compute Recirculation Ratio, Volume of Sludge Produced and Hydraulic Retention Time. Use Equation Block 7-013.

DESIGN OF AERATION SYSTEM

6. Compute Oxygen Requirement and Aeration Power Requirement. Use Equation Block 7-014.
7. Compute Air to Sewage Flow Ratio and Air to BOD Removed Ratio. Use Equation Block 7-014.

If Surface Aerators are used--

8. Check the Zone of Influence Depending upon the Power Requirement of Aerator and Choose the Appropriate Aerator.

If Diffused Aeration System is Used

9. Input: Capacity of Single Diffuser; C_d^{asp}; Number of Diffusers Rows, N_r^{asp}.

10. Compute Number of Diffusers, N_t^{asp}; Their Spacing, y_p^{asp}. Use Equation Block 7-015.

CHECK FOR NUTRIENTS

11. Compute the Amount of Nitrogen and Phosphorous Required for Treatment. Use Equation Block 7-016.

DESIGN OF INFLUENT STRUCTURE

12. Select the Option of Influent Structure-

a) Diffuser Wall with Slots or Perforated Baffles.

b) Influent Channel with Submerged Orfice in the Inside Channel Wall.

c) Influent Channel with Bottom Openings.

d) Overflow Weir Followed by a Baffle.

If the option is any of a, b, c or d, go to 11, 12, 13, and 14 respectively.

13. Input: Spacing of Slots, y_s^{asp}; Permissible Velocity Through Slots, v_s^{asp}. Compute Number of Slots and Their Size. Use Equation Block 7-017.

14. Input: Width of Influent Channel, W_{ic}^{asp}; Number of Orfices, N_o^{asp}; Side of Orifice, S_{or}^{asp} or Diameter of Orfice, d_o^{asp}; In Front Distance of Baffle Wall, x_b^{asp}; Depth D_b^{asp} and Submergence of Baffle Wall, S_w^{asp}. Compute Head Loss in the Influent Structure. Use Equation Block 7-018.

15. Input: Width of Influent Channel, W_{ic}^{asp}; Depth of Influent Channel, D_{ic}^{asp}; Spacing of Openings, y_{op}^{asp}; Permissible Velocity Through Openings, v_{op}^{asp}. Compute Number of Openings and Their Size. Use Equation Block 7-019.

16. Input: Width of Channel, W_{ic}^{asp}; Depth of Channel, D_{ic}^{asp}; Coefficient of Discharge, cd. Compute Head Over Influent Weir. Use Equation Block 7-020.

Effluent Structure

17. Input: Weir Loading Rate, R_w^{asp}; Spacing of V-notches, y_{nh}^{asp}; Width of Effluent Launder, W_{el}^{asp}; Permissible Velocity in Effluent Pipe, v_{ep}^{asp}.

18. Compute the Required Length of Weir, Length of Outlet Zone, Number of Effluent Launders and its Width, Number of V-notches and Head Over the Notches. Use Equation block 7-021.

DESIGN OF SECONDARY CLARIFIER

19. Input: Average Flow, Q_a; Surface Overflow Rate, sor^{sc}; Solid Loading Rate, S_r^{sc}.

20. Put $N^{sc} = 1$

21. Compute Area and Diameter of the Clarifier Based on Surface Overflow Rate, and Solid Loading Rate. Choose the Maximum Value & Calculate the Detention Period. Use Equation Block 7-022.

22. If Diameter of Clarifier > 60 m, Put $N^{sc} = N^{sc} + 1$

INLET & OUTLET STRUCTURE

19. Input: Ratio of Baffle Wall to Tank Diameter, R_{bc}^{sc}; Permissible Velocity Through Ports, v_{pt}^{sc}; Spacing of Ports, y_{pt}^{sc}; Spacing of V-notches, y_{nh}^{sc}; Coefficient of Discharge, cd.

20. Compute Diameter of Baffle Wall, Number of Ports and Their Diameter and Revised Diameter of the Tank. Use Equation Block 7-023.

21. Compute Weir Length, Number of V-notches, and Head Over Them. Use Equation Block 7-023.

22. Display Flow, Length, Width, Depth and Number of Aeration Chambers, Excess Nitrogen and Phosphorous Requirement, Aerator Characteristics, Inlet and Outlet Details.

23. Display Number of Secondary Clarifiers, Diameter and Depth, Inlet and Outlet Characteristics of Secondary Clarifier.

DEFAULT VALUES

$X_s^{asp} = 3000$ mg/l, $D^{asp} = 3$ m, $svi^{asp} = 100$ l/mg, $k_d = 0.05$, $O_{ts}^{asp} = 2.4$ kg O_2/KW-h, $C_d^{asp} = 2.6$ kg O_2/KW-h, $N_r^{asp} = 6$, $y_p^{asp} = 0.75$ m, $sor^{sc} = 25$ $m^3/m^2/d$, $S_l^{sc} = 110$ $kg/m^2/d$, $D^{sc} = 3.0$ m; $y_{pt}^{sc} = 0.75$ m, $v_{pt}^{asp} = 0.9$ m/s, $R_w^{asp} = 125$ $m^3/m/d$, $y_{nh}^{asp} = 0.20$ m.

RANGE

$X_s^{asp} = 2000\text{-}4000$ mg/l, $D^{asp} = 3\text{-}6$ m, $svi^{asp} = 80\text{-}150$ l/mg, $C_d^{asp} = 2.4 - 2.6$ kg O_2/KW-h, $N_r^{asp} = 5\text{-}10$, $y_p^{asp} = 0.5\text{-}0.8$ m, $sor^{sc} = 15\text{-}35$ $m^3/m^2/d$, $S_l^{sc} = 70\text{-}140$ $kg/m^2/d$, $D^{sc} = 3.0\text{-}4.5$ m; $y_{pt}^{sc} = 0.5\text{-}1.0$ m, $v_{pt}^{asp} = 0.9\text{-}1.2$ m/s, $R_w^{asp} = 125\text{-}175$ $m^3/m/d$, $y_{nh}^{asp} = 0.15\text{-}0.25$ m.

EQUATION BLOCK 7-012

1. $Q_{ac}^{asp} = Q_a/N^{asp}$
2. $X^{asp} = 0.8 \times X_s^{asp}$
3. $\mu = 1/bsrt^{asp}$
4. $V^{asp} = [(y_t^{asp} \times Q_{ac}^{asp} \times (S_o - S_e))/(X^{asp} \times (\mu + k_d))]$
5. $A^{asp} = V^{asp}/D^{asp}$
6. $W^{asp} = [A^{asp}/R_{lw}^{asp}]^{1/2}$
7. $L^{asp} = R_{lw}^{asp} \times W^{asp}$

UNITS

Q_{ac}^{asp}, m^3/d; X^{asp}, mg/l; V^{asp}, m^3; A^{asp}, m^2; W^{asp}, m; L^{asp}, m;

EQUATION BLOCK 7-013

1. $X_r^{asp} = 10^6/svi^{asp}$
2. $y_{ob}^{asp} = [y_t^{asp}/(1 + k_d \times bsrt^{asp})]$
3. $hrt^{asp} = L^{asp} \times W^{asp} \times D^{asp} \times 24/Q_{ac}^{asp}$
4. $R_1^{asp} = [hrt^{asp}/(bsrt^{asp} \times 24) - 1]/[1 - X_r^{asp}/X^{asp}]$
5. $\eta^{asp} = [S_o - S_e]/S_o$
6. $X_p^{asp} = y_{ob}^{asp} \times Q_{ac}^{asp} \times (S_o - S_e)/1000$
7. $X_{sp}^{asp} = X_p^{asp}/0.8$
8. $M_s^{asp} = X_{sp}^{asp} - Q_{ac}^{asp} \times S_e/1000$

UNITS

X_r^{asp}, mg/l; hrt^{asp}, h; M_s^{asp}, kg/d; X_{ps}^{asp}, kg/d; X_p^{asp}, kg/d;

EQUATION BLOCK 7-014

1. $O_r^{asp} = [Q_{ac}^{asp}(S_o - S_e)/f - 1.42 \times Q_w^{asp} \times X_r^{asp}]/1000$ $\quad (f = BOD_5/BOD_u)$
2. $O_{rd}^{asp} = 1.5 \times O_r^{asp}$
3. $O_{tc}^{asp} = O_{ts}^{asp} \times (C_s - C_l) \times 1.024^{T_a - 20} \times \alpha/9.17.$
4. $P_r^{asp} = O_r^{asp}/(O_{tc}^{asp} \times 24)$
5. $A_r^{asp} = O_{rd}^{asp}/[\rho_a \times 0.232]$
6. $A_{ar}^{asp} = A_r^{asp}/\eta_{at}^{asp}$
7. $R_{aw}^{asp} = A_{ar}^{asp}/Q_{ae}^{asp}$
8. $R_{ab}^{asp} = A_{ar}^{asp}/Q_{ae}^{asp}(S_o - S_e)$

9. $P_v^{asp} = P_t^{asp}/V^{asp}$

UNITS

O_t^{asp}, kg/d; O_{dt}^{asp}, kg/d; P_t^{asp}, KW; A_t^{asp}, m^3/d;

EQUATION BLOCK 7-015

1. $N_t^{asp} = A_t^{asp}/C_d^{asp}$
2. $N_r^{asp} = W^{asp}/y_p^{asp}$
3. $N_{tt}^{asp} = N_t^{asp}/N_r^{asp}$
4. $y_d^{asp} = L^{asp}/N_{tt}^{asp}$

UNITS

y_d^{asp}, m;

EQUATION BLOCK 7-016

1. $N_e^{asp} = X_p^{asp} \times 0.122 - Q_{ae}^{asp} \times N_t^{asp}/1000$
2. $P_e^{asp} = X_p^{asp} \times 0.023 - Q_{ae}^{asp} \times P_c^{asp}/1000$

UNITS

N_e^{asp}, kg/d; P_e^{asp}, kg/d;

EQUATION BLOCK 7-017

1. $N_s^{asp} = W^{asp} \times D^{asp}/(y_s^{asp})^2$
2. If Slots are Circular

   $d_s^{asp} = [(Q_{ae}^{asp} \times 4)/(v_s^{asp} \times N_s^{asp} \times \pi\ 86400)]^{0.5}$
3. If Slots are Square

   $S_s^{asp} = [Q_{ae}^{asp}/(v_s^{asp} \times N_s^{asp} \times 86400)]^{0.5}$

UNITS

D_s^{asp}, m; S_s^{asp}, m; d_s^{asp}, m

EQUATION BLOCK 7-018

1. $h_l^{asp} = [(pf \times Q_{ae}^{asp})/(N_o^{asp} \times 0.61 \times L_o^{asp} \times W_o^{asp} \times (2g)^{0.5} \times 86400)]^2$

UNITS

h_l^{asp}, m;

EQUATION BLOCK 7-019

1. $N_{op}^{asp} = W_{lc}^{asp} \times L_{lc}^{asp}/(y_{op}^{asp})^2$
2. $S_{op}^{asp} = [Q_{ae}^{asp}/(N_{op}^{asp} \times v_{op}^{asp} \times 86400)]^{0.5}$

UNITS

S_{op}^{asp}, m;

EQUATION BLOCK 7-020

1. $L_{lc}^{asp} = W^{asp}$
2. $H_{lw}^{asp} = [(Q_{ae}^{asp} \times 3)/(2 \times cd \times L_{ch}^{asp} \times (2g)^{0.5} \times 86400]^{2/3}$

UNITS

L_{lc}^{asp}, m; H_{lw}^{asp}, m;

EQUATION BLOCK 7-021

1. $L_w^{asp} = [Q_{ae}^{asp}/R_w^{asp}]$
2. If $W^{asp} > L_w^{asp}$

   $L_w^{asp} = W^{asp}$
3. If $L_w^{asp} <= 4[L_o^{asp} + W^{asp}]$ Where $L_o^{asp} = 0.2 \times L^{asp}$

   Then Provide Weir on Both Sides of Launder in the Outlet Zone

   Else,
4. $N_{ll}^{asp} = [L_w^{asp}/(2 \times L_o^{asp})]$
5. $W_{el}^{asp} = [(W^{asp}/(2 \times N_{ll}^{asp})]$
6. $N_{nh}^{asp} = L_w^{asp}/y_{nh}^{asp}$
7. $d_{ep}^{asp} = [(4 \times Q_{ae}^{asp})/(\pi \times v_{ep}^{asp} \times 86400)]^{0.5}$

UNITS

L_w^{asp}, m; d_{ep}^{asp}, m;

EQUATION BLOCK 7-022

1. $Q_d^{sc} = (Q_{ae}^{sc} + Q_r^{sc} - Q_w^{sc})/N^{sc}$
2. $A_{sor}^{sc} = Q_d^{asp}/sor^{sc}$
3. $A_{sl}^{sc} = Q_d^{sc} \times X_s^{asp}/(S_l^{asp} \times 1000)$
4. A^{sc} = Maximum of these two Areas
5. $d^{sc} = [Asc \times 4/\pi]^{1/2}$

6. $hrt^{sc} = A^{sc} \times d^{sc} \times 24/Q_d^{sc}$

UNITS

Asc, m^2; dsc, m;

EQUATION BLOCK 7-023

1. $d_b^{sc} = R_{bc}^{sc} \times d^{sc}$
2. $N_{pt}^{sc} = [\pi \times d^{sc} \times d_b^{sc}/(2 \times (y_{pt}^{sc})^2)]$
3. $A_{pt}^{sc} = Q_d^{sc}/v_{pt}^{sc} \times 86400$
4. $d_{pt}^{sc} = [\{A_{pt}^{sc} - \pi \times (d_b^{sc})^2\}/(4 \times N_{pt}^{sc})]$
5. $d_{rc}^{sc} = [(d_b^{sc})^2 + (d^{sc})^2]^{1/2}$
6. $L_w^{sc} = Q_d^{sc}/R_w^{sc}$

   If $\pi \times d_{rc}^{sc} > L_w^{sc}$

   $L_w^{sc} = \pi \times d_{rc}^{sc}$

   (Provide Notches on Single Side of Periphery)

   Else Provide Notches on both Sides of Periphery.

   $L_w^{sc} = 2 \times \pi \times d_{rc}^{sc}$
7. $N_{nh}^{sc} = L_w^{sc}/y_{nh}^{sc}$
8. $H_{nh}^{sc} = [(Q_d^{sc} \times 15)/(N_{nh}^{sc} \times 8 \times cd \times (2g)^{1/2} \times 86400]^{2/5}$

UNITS

d_b^{sc}, m; A_{pt}^{sc}, m^2; d_{pt}^{sc}, m; d_{rc}^{sc}, m; L_w^{sc}, m; H_{nh}^{sc}, m;

7.14 Design of Trickling Filter

BY NRC EQUATION

1. Input: Average Flow; Q_a; Influent BOD, S_o; Effluent BOD, S_e;
2. If the Filter is Single Stage go to 3, else go to 5.
3. Input: Recirculation Ratio, R_1^t; Depth of Filter, D_1^t;.
4. Put $N_1^t = 1$
5. Compute the Efficiency, Volume of Filter, and its Diameter. Use Equation Block 7-025. Go to 7.
6. If Diameter Exceeds 60 m, $N_1^t = N_1^t + 1$

23 Compute Number of Laterals and Their Diameters, and Diameter of Main Collecting Channel. Use Equation Block 7-030.

24 Display Flow, Peaking Factor, Number of Trickling Filters, Depth of Filter, Diameter of Filter, Recirculation at First and Second Stage, Diameter of Central Column, Number of Arms and Sections, Length of Each Arm & Each Section, Number of Orfices and Diameter of Each Orfice.

DEFAULT VALUES

$O_1{}^t = 0.8$ Kg/m^3-d, $R_1{}^t = 1.0$, $D_1{}^t = 1.0$ m, $v_{cc}{}^t = 1.2$ m/s, $N_a{}^t = 2$, $N_{sc}{}^t = 3$, $v_{sc}{}^t = 1.0$ m/s, $O_2{}^t = 0.8$ kg/m^3-d, $R_2{}^t = 1.0$, $D_2{}^t = 1.0$.

RANGE

$O_1{}^t = 0.32\text{-}1.0$ Kg/m^3-d, $R_1{}^t = 0.5\text{-}3.0$, $D_1{}^t = 1.0$ m, $v_{cc}{}^t = 1.0\text{-}2.0$ m/s, $N_a{}^t = 2\text{-}4$, $N_{sc}{}^t = 2\text{-}4$, $v_{sc}{}^t = 0.8\text{-}1.5$ m/s, $O_2{}^t = 0.32\text{-}1.0$ kg/m^3-d, $R_2{}^t = 0.5\text{-}3.0$, $D_2{}^t = 1.0\text{-}1.5$.

EQUATION BLOCK 7-024

1. $Q_{ae}{}^t = Q_a/N_1{}^t$
2. $W_1{}^t = Q_{ae}{}^t \times S_o/1000$
3. $\eta_1{}^t = [(S_o - S_e)/S_o]$
4. $F_1 = [(1 + R_1{}^t)/(1 + 0.1 \times R_1{}^t)^2]$
5. Compute Volume of Filter from the Following Expression
   $\eta_1{}^t = [1/(1+0.44(W_1{}^t/V_1{}^t \times F_1)^{1/2})]$
6. $A_1{}^t = V_1{}^t/D_1{}^t$
7. $d_1{}^t = [(4 \times A_1{}^t)/\pi]^{1/2}$.

UNITS

$Q_{ae}{}^t$, m^3/d; $V_1{}^t$, m^3; $A_1{}^t$, m^2; $d_1{}^t$, m

EQUATION BLOCK 7-025

1 $Q_{ae}{}^t = Q_a/N_1{}^t$

2 $W_1{}^t = Q_{ae}{}^t \times S_o/1000$

3 $V_1{}^t = W_1{}^t/O_1{}^t$

4 $F_1 = [(1+R_1{}^t)/(1+0.1 \times R_1{}^t)^2]$

5 $F_2 = [(1 + R_2^t)/(1 + 0.1 \times R_2^t)^2]$

6 $\eta_t^t = [(S_o - S_e)/S_o]$

7 $\eta_1^t = [1/(1+0.44(W_1^t/V_1^t \times F_1)^{1/2})]$

8 $\eta_2^t = \eta_t^t - \eta_1^t$

9 $V_2^t = [1/(1+0.44(W_1^t/V_1^t \times F_1 \times (1 - \eta_1^t)^{1/2})]$

10 $d_1^t = [(4 \times V_1^t)/(\pi \times D_1^t)]^{1/2}$

11 $d_2^t = [(4 \times V_2^t)/(\pi \times N_2^t \times D_2^t)]^{1/2}$

UNITS

W_1^t, kg/d; V_1^t, m^3; d_1^t, m; D_1^t, m;

EQUATION BLOCK 7-026

1 $Q_{ae}^t = Q_a/N_1^t$

2 $W_1^t = Q_{ae}^t \times S_o/1000$

3 $\eta_1^t = [(S_o - S_e)/S_o]$

4 $V_1^t = W_1^t/O_1^t$

5 $A_1^t = V_1^t/D_1^t$

6 $d_1^t = [(4 \times A_1^t)/\pi]^{1/2}$

7 Compute R_1^t. $\eta_1^t = [(1+R_1^t)/(1.5 + R_1^t)]$

8 $S_{e1}^t = [S_o + R_1^t \times S_e)/(1+ R_1^t)]$

UNITS

Q_{ae}^t, m^3/d; W_1^t, kg/d; V_1^t, m^3; d_1^t, m; D_1^t, m;

EQUATION BLOCK 7-027

1 $Q_{ae}^t = Q_a/N_1^t$

2 $W_1^t = Q_{ae}^t \times S_o/1000$

3 $\eta_o^t = [(S_o - S_e)/S_o]$

4 $V_1^t = W_1^t/O_1^t$

5 $A_1^t = V_1^t/D_1^t$

6 $d_1^t = [(4 \times A_1^t)/\pi]^{1/2}$

7 $\eta_1^t = [(1+R_1^t)/(1.5+R_1^t)]$

8 $\eta_2^t = \eta_t^t - \eta_1^t$

9 Compute R_2^t from the Expression $\eta_2^t = [(1+R_2)/(2+R_2)]$

10 $S_{e1}^t = (1-\eta_1^t) \times S_o$

11 $H_1^t = \{Q_{ae}^t(S_o + R_1 \times S_{e1}^t) \times 4\}/\{N_1^t \times (d_1^t)^2 \times \pi \times D_1^t \times 1000\}$

12 $V_2^t = (Q_{ae}^t \times S_{e1}^t)/(O_2^t \times 1000)$

13 $d_2^t = [(V_2^t \times 4)/N_2^t \times D_2^t \times \pi]^{1/2}$

14 $H_2^t = [Q_{ae}^t(S_{e1}^t + R_2^t \times S_e\} \times 4]/[N_2^t \times (d_1^t)^2 \times \pi \times D_1^t \times 1000]$

UNITS

Q_{ae}^t, m^3/d; W_1^t, kg/d; W_2^t, kg/d; H_1^t, kg/m^3-d; H_2^t, kg/m^3-d; V_1^t, m^3; V_2^t, m^3; D_1^t, m; D_2^t, m; d_1^t, m; d_2^t, m;

EQUATION BLOCK 7-028

1 $Q_{ae}^t = Q_a/N_1^t$

2 $Q_d^t = [(pf + R_1^t) \times Q_{ae}^t]$

3 $Q_{ad}^t = [(1+R_1^t) \times Q_{ae}^t]$

4 $d_{cc}^t = [(Q_d^t \times 4)/(\pi \times v_{cc}^t)]$

5 $v_a^t = [(Q_{ae}^t \times 4)/\pi \times (d_{cc}^t)^2]$

6 $Q_{aa}^t = Q_d^t/N_a^t$

7 $L_a^t = [(d_f^t - d_{cc}^t)/2]$

8 $L_{as}^t = L_a^t/N_{sc}^t$

9 $A_{si}^t = \pi[(i \times L_{sc}^t + d_{cc}^t/2)^2 - ((i-1) \times L_{sc}^t + D_{cc}^t/2)^2]$

10 $r_{is}^t = [A_{si}^t/\Sigma A_{si}^t]$

11 $Q_o^t = [cd \times \pi \times (d_o^t)^2 \times (2 \times g \times H^t)^{1/2})/4]$

12 $N_o^t = Q_{ar}^t/Q_o^t$

13 $N_{os}^t[i] = r_i \times N_o^t$ at $100L/N_{os}^t[i]$ cm c/c

14 $d_{ss}^t = [(1-\Sigma r_i) \times Q_{aa}^t/(\pi \times v_a^t)]$

UNITS

Q_d^t, m^3/d; d_{cc}^t, m; v_{cc}^t, m/s; L_a^t, m; L_{sc}^t, m; A_{sc}^t, m^2; d_{sc}^t, m;

EQUATION BLOCK 7-029

$N_l^t = d_l^t / y_l^t$

$Q_l^t = [Q_d^t/(2 \times N_l^t)]$

UNITS

Q_l^t, m^3/d; Q_d^t, m^3/d;

7.15 Design of Aerobic Pond

1. Input: Average Flow, Q_a; Influent BOD, S_o; Effluent BOD, S_e; Latitude, LL^{ap}; Ambient Temperature, T_a; Influent Water Temperature, T_w^{ap}; Sky Clearance Factor, S_f^{ap}; Ratio of Oxygen to Algae, R_{oa}^{ap}; Heat of Combustion, H_c^{ap}; Minimum Radiation, R_{mn}^{ap}; Maximum Radiation, R_{mx}^{ap}; Elevation Above MSL, E^{ap}; Ratio of Length to Width, R_{lw}^{ap}; Depth, D^{ap}; Efficiency of Energy Transfer, η_{et}^{ap}; Population, P; Sludge per Capita, Q_{sp}^{ap}; Influent Coliforms, C_o^{ap}, Number of Ponds in Parallel, N_{pp}^{ap}; Number of Ponds in Series, N_{ps}^{ap}.
2. Compute Area of Pond Based on latitude and Temperature Conditions. Use Equation Block 7-030.
3. Compute Area of Pond based on Algae Growth Condition. Use Equation Block 7-031.
4. Compute Length, Width, Depth, Detention Period, Effluent BOD, Sludge Produced, Effluent Coliforms and Total Depth of Pond. Use Equation Block 7-032.
5. Display Design Flow, Number of Ponds in Series, Number of Ponds in Parallel, Length, Width, Depth, Effluent BOD, Sludge Produced and Effluent Coliform Concentration.

DEFAULT VALUES

$N_{ps}^{ap} = 1.0$, $N_{pp}^{ap} = 1.0$, $LL^{ap} = 28^0$, $T_w^{ap} = 20^0c$, $S_f^{ap} = 75\%$, $E^{ap} = 100m$.

RANGE

$N_{ps}^{ap} = 1.0\text{-}5.0$, $N_{pp}^{ap} = 1.0\text{-}5.0$, $LL^{ap} = 8\text{-}36^0$, $T_w^{ap} = 20\text{-}35^0c$, $S_f^{ap} = 75\text{-}90\%$, $E^{ap} = 100\text{-}150$ m.

EQUATION BLOCK 7-030

1. $W_1^{ap} = Q_a \times S_o/1000$
2. $O_l^{ap} = (325 - 6.25 \times (LL^{ap}-8))/(1+0.003 \times E^{ap})$

3. $O_t^{ap} = 20 \times T_a - 120$

4. $A_t^{ap} = W_1^{ap}$ /(Minimum of 2 & 3)

If $S_f^{ap} < 75\%$

5 $A_m^{ap} = A^{ap} \times [1 + 0.03/10(75 - S_f^{ap})]$

UNITS

W_1^{ap}, kg/d; O_t^{ap}, kg/m^2-d; A^{ap}, m^2;

EQUATION BLOCK 7-

1. $O_t^{ap} = Q_a \times (S_o - S_e)/1000$
2. $W_a^{ap} = O_t^{ap}/R_{oa}^{ap}$
3. $E_r^{ap} = W_a^{ap} \times H_c^{ap}$
4. $R_a^{ap} = R_{mn}^{ap} + (R_{mx}^{ap} - R_{mn}^{ap}) \times S_f^{ap} \times 10^6$
5. $R_{ev}^{ap} = R_a^{ap} \times (1 + 0.003 \times E^{ap})$
6. $E_a^{ap} = \eta_{et}^{ap} \times R_{ev}^{ap}$
7. $A_h^{ap} = E_r^{ap} / E_a^{ap}$

UNITS

O_t^{ap}, kg/d; W_a^{ap}, kg/d; E_r^{ap}, KJ/d; A_h^{ap}, m^2;

EQUATION BLOCK 7-032

1. $Q_{ae}^{ap} = Q_a/N_{pp}^{ap}$
2. $A^{ap} = A_t^{ap}/(N_{pp}^{ap} \times N_{ps}^{ap})$
3. $hrt^{ap} = A^{ap} \times D^{ap}/Q_{ae}^{ap}$

Pond Temperature may be Computed from the Expression .

$$hrt^{ap}/D^{ap} = (T_w^{ap} - T_p^{ap})/[f \times (T_p^{ap} - T_a)]$$

$K_t = K_{20} \times 1.047^{(Tpap-20)}$

5 $S_e^{ap} = S_0/[1 + K_t \times hrt^{ap}]N_{ps}^{ap}$

6 $W^{ap} = [A^{ap}/R_{lw}^{ap}]^{1/2}$

7. $L^{ap} = W^{ap} \times R_{lw}^{ap}$

8. $Q_s^{ap} = P \times t_c^{ap} \times Q_{sp}^{ap}$

9. $D_{sl}^{ap} = Q_s^{ap}/(A^{ap} \times N_{ps}^{ap} \times N_{pp}^{ap})$

10. $D_t^{ap} = D^{ap} + D_{sl}^{ap} + F_b^{ap}$

11. $K_{bt} = (K_b)_{20} \times 1.19^{(Tpap-20)}$

12. $C_e^{ap} = C_0^{ap}/[1 + K_{bt} \times hrt^{ap}]^{N_{ps}^{ap}}$

UNITS

Q_{ae}^{ap}, m^3/d; A^{ap}, m^2; L^{ap}, m; W^{ap}, m; D_p^{ap}, m; Q_s^{ap}, m^3/d; D_s^{ap}, m; D_t^{ap}, m; C_e^{ap}, org/100ml.

7.16 Design of Facultative Pond

1. Input: Average Flow, Q_a; Ambient Temperature, T_a; Latitude, LL^{fp}; Influent Water Temperature, T_w^{fp}; Elevation Above MSL, E^{fp}; Influent BOD, S_o; Number of Ponds in Parallel, N_{pp}^{fp}; Number of Ponds in Series, N_{ps}^{fp}; Depth, D^{fp}; Ratio of Length to Width, R_{lw}^{fp}; Number of Baffle Wall, N_b^{fp}; Influent Coliform Concentration, C_o^{fp}; Sludge/Capita-Year, Q_{sp}^{fp}.
2. Compute Area of Pond and its Configuration. Use Equation Block 7-033.
3. Compute Effluent BOD, Total Depth, Sludge Quantity and Effluent Coliforms. Use Equation Block 7-034.
4. Display Flow, Number of Ponds in Parallel, Number of Ponds in Series, Length, Width, Total Depth, Number of Baffle Walls, Effluent BOD, Effluent Coliforms and Sludge Produced.

DEFAULT VALUES

$N_{pp}^{fp} = 1$, $N_{ps}^{fp} = 1$, $D^{fp} = 1.5$ m, $Q_{sp}^{fp} = 0.07$ m^3/person/a, $N_b^{fp} = 1$, $LL^{fp} = 28^0$, $T_w^{fp} = 20^0c$, $E^{fp} = 100$ m, $R_{lw}^{fp} = 8.0$.

RANGE

$N_{pp}^{fp} = 1\text{-}5$, $N_{ps}^{fp} = 1\text{-}5$, $D^{fp} = 1.0\text{-}2.0$ m, $N_b^{fp} = 1\text{-}5$, $LL^{fp} = 8\text{-}36^0$, $T_w^{fp} = 20\text{-}40^0c$, $E^{fp} = 100\text{-}150$ m, $R_{lw}^{fp} = 4.0\text{-}12.0$.

EQUATION BLOCK 7-033

1. $O_t^{fp} = 20 \times (T_a - 120)$
2. $O_l^{fp} = [325 - 6.25 \times (LL^{fp} - 8)]/[(1+0.003 \times E^{fp})]$
3. $W_p^{fp} = Q_a \times S_o/1000$
4. $A_t^{fp} = W_p^{fp}$/Minimum of Loading Rates(1 & 2)
5. $A^{fp} = A_t^{fp}/(N_{pp}^{fp} \times N_{ps}^{fp})$
6. $W^{fp} = [A^{fp}/R_{lw}^{fp}]^{0.5}$
7. $L^{fp} = W^{fp} \times R_{lw}^{fp}$

8. $L_e^{fp} = L^{fp} \times (1 + N_b^{fp})$

9. $W_e^{fp} = W^{fp}/(1 + N_b^{fp})$

UNITS

Q_a, m^3/d, O_l^{fp}, kg/m^2-d; W_p^{fp}, kg/d; A^{fp}, m^2; L^{fp}, m; W^{fp}, m; L_e^{fp}, m; W_e^{fp}, m;

EQUATION BLOCK 7-034

1. Compute Dispersion Coefficient D_s^{fp}

If $W_e^{fp} > 30$ m

$D_s^{fp} = 33 \times W_e^{fp}$ (With Baffles)

$D_s^{fp} = 16.7 \times W_e^{fp}$ (Without Baffles)

If $W_e^{fp} < 10$m

$D_s^{fp} = 11 \times (W_e^{fp})^2$ (With baffles)

$D_s^{fp} = 2 \times (W_e^{fp})^2$ (Without baffles)

else

$D_s^{fp} = 1100 - 5.5 \times (W_e^{fp} - 10)$ (With Baffles)

$D_s^{fp} = 200 + 15.05 \times (W_e^{fp} - 10)$ (Without Baffles)

2. $D_n^{fp} = D_s^{fp} \times hrt^{fp} \times 24/(L_e^{fp})^2$

3. Find Out the Pond Temperature from the Expression

$hrt^{fp}/D^{fp} = (T_w^{fp} - T_p^{fp})/[f \times (T_w^{fp} - T_a)]$

4. $K_t = K_{20} \times 1.035^{Twfp-20}$

If the Design Approach is Completely Mixed Reactor Approach

5. $S_e = S_o/[\{1 + K_t \times (hrt^{fp}/N_{ps}^{fp})\}N_{ps}^{fp} + \{0.77 \times 0.6 \times tss_e^{fp}\}]$

If Design Approach is Dispersed Flow Reactor -

5a. Compute $S_e/S_o = [4 \times a \times e^{Dn/2}/\{(1+a)^2 \times e^{a/2Dn} - (1-a)^2 \times e^{-a/2Dn}\}]$

Where $a = [1 + 4 \times K_t \times hrt^{fp} \times D_n^{fp}]^{1/2}$

5b. $S_{ef} = S_o \times (1 - S_e/S_o)^{Npsfp}$

6. $\eta_o^{fp} = [S_o - S_{ef}]/S_o$

7. $K_{bt} = (K_b)_{20} \times 1.19^{(Twfp-20)}$

8. Effluent Coliforms can be Found out as BOD has been Found Out in Step 5, Depending upon the Design Approach Adopted and Replacing K_t by K_{bt}.

9. $Q_s^{fp} = Q_{sp}^{fp} \times P \times t_c^{fp}$

10. $D_{sz}^{fp} = Q_s^{fp}/A_t^{fp}$

11. $D_t^{lp} = D^{lp} + F_b^{lp} + D_{sz}^{lp}$

UNITS

T_w^{lp}, ^0c; Q_{sp}^{lp}, kg/d; D_{sz}^{lp}, m; D_t^{lp}, m;

7.17 Design of Aerated Lagoons

1. Input: Average Flow, Q_a; Depth, D^{al}; Ratio of Length to Width, R_{lw}^{al}; Temperature of Influent WW, T_w^{al}; Temperature of Ambient Air, T_a; Hydraulic Retention Time, hrt^{al}; BOD Removal Rate Constant at 20^0C, K_{20}; Yield Coefficient, y_t^{al}; Influent BOD, S_o; Aerator Capacity, A_c^{al}; Ratio of BOD_5 and VSS, R_{bv}^{al}; Influent Coliform, C_o^{al}.
2. Put $N^{al} = 1$
3. Compute Lagoon Volume, Length, Width, Temperature, Effluent BOD, and Efficiency of Aerated Lagoon. Use Equation Block 7-035.
4. If Length > 300 m, $N^{al} = N^{al} + 1$
5. Compute the Oxygen Requirement, Power Requirement and Coliforms in the Effluent. Use Equation Block 7-036.
6. Display Design Flow, Number of Lagoons, Length, Width, Depth, Number of Longitudinal Baffles, Detention Period, Effluent BOD, Oxygen Required and Quantity of Sludge Produced.

DEFAULT VALUES

$N_b^{al} = 0$, $hrt^{al} = 4$ d, $D^{al} = 1.5$ m, $R_{lw}^{al} = 4.0$, $R_{bv}^{al} = 0.6$

RANGE

$N_b^{al} = 0\text{-}5$, $hrt^{al} = 3\text{-}10$ d, $D^{al} = 1.5\text{-}2.5$ m, $R_{lw}^{al} = 2.0\text{-}16.0$, $R_{bv}^{al} = 0.6\text{-}0.7$

EQUATION BLOCK 7-035

1. $Q_{ae}^{al} = Q_a/N^{al}$
2. $V^{al} = Q_{ae}^{al} \times hrt^{al}$
3. $A^{al} = V^{al}/D^{al}$
4. $W^{al} = [A^{al}/R_{lw}^{al}]^{1/2}$
5. $L^{al} = W^{al} \times R_{lw}^{al}$
6. Compute Lagoon Temperature from the Given Expression

$$hrt^{al}/D^{al} = [(T_w^{al} - T_L^{al})/(f \times (T_L^{al} - T_a))]$$

7. $K_t = K_{20}(1.035)^{T_l^{al}-20}$

8. $S_e = S_o/[1+K_t \times hrt^{al}]$

9. $X_l^{al} = [y_t^{al}(S_o - S_e)/(1+k_d \times hrt^{al})]$

10. $S_{ef} = S_e + [(S_o/X_l^{al}) \times X_l^{al}]$

11. $\eta_o^{al} = [(S_o - S_{ef})/S_o]$

UNITS

V^{al}, m^3; A^{al}, m^2; L^{al}, m; W^{al}, m; D^{al}, m; S_{ef}, mg/l;

EQUATION BLOCK 7-036

1. $O_r^{al} = [\{Q_{ae}^{al} \times (S_o - S_e) \times 10^{-3}/f\} - 1.42 \times (Q_{ae}^{al} \times X_l^{al} \times 10^{-3})]$
2. $P_r^{al} = O_r^{al}/A_c^{al}$
3. $P_v^{al} = P_r^{al}/V^{al}$

   If $P_v^{al} < P_{vm}^{al}$, $P_r^{al} = P_{vm}^{al} \times V^{al}$
4. $K_{bt} = (K_b)_{20} \times 1.19^{Tl-20}$
5. $C_e^{al} = C_o^{al}/(1+K_{bt} \times hrt^{al})$

UNITS

O_r^{al}, kg/d; P_r^{al}, KW; C_e^{al}, org/100 ml.

7.18 Design of Facultative Lagoon

1. Input: Average Flow, Q_a; Depth, D^{fl}; Ratio of Length to Width, R_{lw}^{fl}; Temperature of Influent WW, T_w^{fl}; Temperature of Ambient Air, T_a; Hydraulic Retention Time, hrt^{fl}; Lagoons in Parallel, N_{lp}^{fl}; Lagoons in Series, N_{ls}^{fl}; TSS Concentration, tss_t^{fl}; K_{20}; Yield Coefficient, y_t^{fl}; Influent BOD, S_o; Effluent BOD, S_e; Aerator Capacity, A_c^{fl}; Ratio of BOD/VSS, R_{bv}^{fl}; Sludge per Capita, Q_{sp}^{fl}; Cleaning Frequency, t_c^{fl}; Influent Coliforms, C_o^{fl}.

2. Compute Length, Width and Depth of the Lagoon. Use Equation Block 7-037.

3. Compute Dispersion Number, Effluent BOD, Effluent Coliforms and Overall Efficiency. Use Equation Block 7-038.

4. Compute Oxygen Requirement, Power Requirement and Quantity of Sludge Accumulated. Use Equation block 7-039.

5. Display Flow Rate, Lagoons in Series, Lagoons in Parallel, Hydraulic Retention Time, Length, Width, Depth, Number of Longitudinal Baffles, Lagoon Temperature, Effluent BOD, Effluent Coliforms, Sludge Produced, Diameter of Influent Pipe, Length, Width and Depth of Influent Channel and Number of Notches.

DEFAULT VALUES

$hrt^{fl} = 4$ d, $D^{fl} = 2.0$ m, $N_{lp}^{fl} = 1$, $N_{ls}^{fl} = 1$, $R_{lw}^{fl} = 8.0$, $N_{b}^{fl} = 0$, $K_{20} = 0.6$, $tss_{i}^{fl} = 100$ mg/l, $T_{w} = 25^{0}$ c, $t_{c}^{fl} = 5$ a, $A_{c}^{fl} = 2.5$ kg/KW h, $Q_{sp}^{fl} = 0.08$ kg, $P_{v}^{fl} = 0.75$, $K_{b20} = 1.6$.

RANGE

$hrt^{fl} = 3\text{-}5$ d, $D^{fl} = 2.0\text{-}5.0$ m, $N_{lp}^{fl} = 1\text{-}5$, $N_{ls}^{fl} = 1\text{-}5$, $R_{lw}^{fl} = 4.0\text{-}16.0$, $N_{b}^{fl} = 0\text{-}5$, $tss_{i}^{fl} = 100\text{-}300$ mg/l, $T_{w} = 25\text{-}40^{0}$ c, $t_{c}^{fl} = 3\text{-}7$ a, $A_{c}^{fl} = 2.4\text{-}2.6$ kg/KW h, $Q_{sp}^{fl} = 0.05\text{-}0.12$ kg, $P_{v}^{fl} = 0.75\text{-}2.0$

EQUATION BLOCK 7-037

1 $Q_{ac}^{fl} = Q_{a}/N_{lp}^{fl}$

2. $V^{fl} = Q_{ac}^{fl} \times hrt^{fl}$

3. $A^{fl} = V^{fl}/D^{fl}$

4. $W^{fl} = [A^{fl}/R_{lw}^{fl}]^{1/2}$

5. $L^{fl} = R_{lw}^{fl} \times W^{fl}$

6. $L_{e}^{fl} = L^{fl} \times (1 + N_{b}^{fl})$

7. $W_{e}^{fl} = W^{fl}/(1 + N_{b}^{fl})$

UNITS

V^{fl}, m^{3}; A^{fl}, m^{2}; W^{fl}, m; L^{fl}, m; L_{e}^{fl}, m; W_{e}^{fl}, m;

EQUATION BLOCK 7-038

1. Compute Dispersion Coefficient D_{s}^{fl}

If $W_{e}^{fl} > 30$ m

$D_{s}^{fl} = 33 \times W_{e}^{fl}$ (With Baffles)

$D_{s}^{fl} = 16.7 \times W_{e}^{fl}$ (Without Baffles)

If $W_{e}^{fl} < 10$m

$D_{s}^{fl} = 11 \times (W_{e}^{fl})^{2}$ (With baffles)

$D_{s}^{fl} = 2 \times (W_{e}^{fl})^{2}$ (Without baffles)

else

$D_s^{fl} = 1100 + 5.5 \times (W_e^{fl} - 10)$ (With Baffles)

$D_s^{fl} = 200 + 15.05 \times (W_e^{fl} - 10)$ (Without Baffles)

2. $D_n^{fl} = D_s^{fl} \times hrt^{fl} \times 24/(L_e^{fl})^2$

3. Find Out the Pond Temperature from the Expression

$hrt^{fl}/D^{fl} = (T_w^{fl} - T_p^{fl})/[f \times (T_w^{fl} - T_a)]$

5. $K_t = K_{20} \times 1.035^{Twfl-20}$

If the Design Approach is Completely Mixed Reactor Approach

12. $S_e = S_o/[\{1+K_t \times hrt^{fl}/N_{ls}^{fl}\}N_{ls}^{fl} + \{0.77 \times 0.6 \times tss_e^{fl}\}]$

If Design Approach is Dispersed Flow Reactor -

5a. Compute $S_e/S_o = [4 \times a \times e^{1/2Dn}/\{(1+a)^2 \times e^{a/2Dn} - (1-a)^2 \times e^{-a/2Dn}\}]$

Where $a = [1+4 \times K_t \times hrt^{fl} \times D_n^{fl}]^{1/2}$

5b. $S_{ef} = (1-S_e/S_o)N_{ps}^{fl} \times S_o$

13. $\eta_o^{lp} = [S_o - S_{ef}]/S_o$

14. $K_{bt} = (K_b)_{20} \times 1.19^{(Twfl-20)}$

15. Effluent Coliforms can be Found out as BOD has been Found Out in Step 5, Depending upon the Design Approach Adopted and Replacing K_t by K_{bt}.

16. $Q_s^{fl} = Q_{sp}^{fl} \times P \times t_c^{fl}$

17. $D_{sz}^{fl} = Q_s^{fl}/A_t^{fl}$

18. $D_t^{fl} = D^{fl} + F_b^{fl} + D_{sz}^{fl}$

UNITS

T_w^{fl}, ^0C; Q_{sp}^{fl}, kg/d; D_{sz}^{fl}, m; D_t^{fl}, m;

EQUATION BLOCK 7-039

1. $O_t^{fl} = 1.4 \times Q_{ae}^{fl} \times (S_o - S_e)/24$
2. $P_{rm}^{fl} = P_v^{fl} \times V^{fl}$

Choose the Maximum of Above These Values.

UNITS

O_t^{fl}, kg/d; P_{rm}^{fl}, KW;

7.19 Design of Oxidation Ditch

1. Input: Average Flow, Q_a; Influent BOD, S_o; Effluent BOD, S_e; MLSS, X^{od}; F/M Ratio, R_{fm}^{od}; Sludge Volume Index(SVI), svi^{od}; Oxygen Required Per kg of BOD Removed, O_b^{od}; Oxygenation Capacity of Rotor, O_{lc}^{od}; Volume Treated Per Unit Length of Rotor, V_r^{od}; Number of Rotors, N_r^{od}; Clearance, C; Power Required Per Unit Length of Rotor, P_l^{od}; Depth of Ditch, D^{od}.
2. Input: Surface Overflow Rate, sor^{sc}; Depth of Clarifier, D^{sc}.
3. Compute Efficiency, Total BOD to be Removed, Volume of Ditch, Hydraulic Retention Time, Return Sludge and Volumetric Loading for the Oxidation Ditch. Use Equation Block 7-040.
4. Compute the Oxygen Requirement and the Length of the Rotor Required. Use Equation Block 7-041.
5. Compute Top Width, Bottom Width, Length of Ditch, and Power Requirement. Use Equation Block 7-042.
6. Put $N^{sc} = 1$
7. Compute Dimension of Clarifier. Use Equation Block 7-043.
8. If $d^{sc} > 60$ m, Put $N^{sc} = N^{sc} + 1$
9. Display Design Flow, Number of Units, Length of Ditch, Top Width of Ditch, Bottom Width of Ditch, Depth of Ditch, Number of Rotors, Oxygen Required, Volumetric Loading, Sludge Recirculation, Power Requirement.
10. Display Surface Overflow Rate, Number of Clarifiers, Diameter and Depth of Clarifier.

DEFAULT VALUES

X_s^{od} = 3000 mg/l, R_{fm}^{od} = 0.1 kg BOD/kg MLSS, svi^{od} = 100 l/mg, O_b^{od} = 1.2, O_c^{od} = 2.8 kg of O_2/h, V_l^{od} = 120 m^3, P_l^{od} = 1.8 hp/m, D^{od} = 1.0 m, sor^{sc} = 14 $m^3/d/m^2$, D^{sc} = 3.5 m.

RANGE

X_s^{od} = 3000-5000 mg/l, R_{fm}^{od} = 0.1-0.3 kg BOD/kg MLSS, svi^{od} = 80-150 l/mg, O_b^{od} = 1.0-1.2, O_c^{od} = 2.6-2.8 kg of O_2/h, V_l^{od} = 120-150 m^3, P_l^{od} = 1.8-2.0 hp/m, D^{od} = 1.0-1.5 m, sor^{sc} = 8-15 $m^3/d/m^2$, D^{sc} = 3.5-4.5 m.

EQUATION BLOCK 7-040

1. $O_l^{od} = Q_a \times S_o/1000$
2. $O_r^{od} = Q_a \times (S_o - S_e)/1000$
3. $\eta = [(S_o - S_e)/S_o]$
4. $V^{od} = [(Q_a \times S_o)/(X_s^{od} \times R_{fm}^{od})]$
5. $hrt^{od} = V^{od} \times 24/Q_a$
6. $V_l^{od} = [(Q_a \times S_o)/(V^{od} \times 1000)]$
7. $R_1 = [X_s^{od}/(10^6/svi^{od} - X_s^{od})]$

UNITS

O_l^{od}, kg/d; O_r^{od}, kg/d; V^{od}, m^3; hrt^{od}, h; V_l^{od}, kg BOD/m^3;

EQUATION BLOCK 7-041

1. $O_r^{od} = O_b^{od} \times O_r^{od}/24$
2. $L_{ro}^{od} = O_r^{od}/O_{rc}^{od}$
3. $L_{rc}^{od} = V^{od}/V_l^{od}$.
4. L_r^{od} = Maximum of Above Two Values.
5. $N^{od} = Int\{(L_r^{od}/15) + 0.5\}$

UNITS

O_r^{od}, kg/h; L_r^{od}, m;

EQUATION BLOCK 7-042

1. $L_{re}^{od} = L_r^{od}/N^{od}$
2. $W_{tp}^{od} = L_{re}^{od}/2 + 2 \times C$
3. $W_{bt}^{od} = W_{tp}^{od} - 2 \times D^{od}$
4. $A^{od} = W_{bt}^{od} \times D^{od} + D^{od} \times D^{od}$
5. $C_r^{od} = \pi \times D^{od}$
6. $V_{st}^{od} = V^{od}/N^{od} - A^{od} \times C_r^{od}$
7. $L_m^{od} = V_{st}^{od}/A^{od}$
8. $L_t^{od} = L_m^{od}/2 + 2 \times D^{od}$

UNITS

L_r^{od}, m; L_{bt}^{od}, m; L_{tp}^{od}, m; A^{od}, m^2; L_t^{od}, m;

EQUATION BLOCK 7-043
1. $A^{sc} = [Q_a/(N^{sc} \times sor^{sc})]$
2. $d^{sc} = [A^{sc} \times 4/\pi]^{1/2}$
UNITS
sor^{sc}, m^2; d^{sc}, m;

7-20 Design of Upflow Anaerobic Sludge Blanket (UASB) Reactor

1. Input: Average Flow, Q_a; Hydraulic Retention Time at Average Flow, hrt^{ur}; Hydraulic Retention Time at Peak Flow, hrt_p^{ur}; Peaking Factor, pf; Depth, D^{ur}; Ratio of Length to Width, R_{lw}^{ur}; Spacing of GLSS Separators, y_{gs}^{ur}; Manning's Coefficient;n, Spacing of Primary Feeder Channels, y_{pf}^{ur}.
2. Compute Volume, Area, Depth, Length and Width(Rectangular Reactor) or Diameter of Reactor. Use Equation Block 7-044.
3. Compute Number of GLSS Separators, Number of Feeder Channels, Total Number of Primary and Secondary Feeders and Discharge in Them. Use Equation Block 7-045.

DESIGN OF INFLUENT CHANNELS

4. Input: Permissible Velocity Through Each Channel, v_{pc}^{ur}; Bottom Width, W_{bi}^{ur}; Permissible Velocity Through Primary Feeder Pipe, v_{pp}^{ur}.
5. Compute Area Served by Each Primary and Secondary Feeders, Depth of Flow in the Influent Channel (Assuming it to be Rectangular and Fed from Both Sides), Diameter of Primary Feeder, Slope of the Influent Channel and Spacing of the Holes. Use Equation Block 7-046.
6. Compute Aperture Length and Aperture Width. Use Equation Block 7-047.

DESIGN OF EFFLUENT COLLECTION WEIR AND DISTRIBUTION BOX

7. Input: Bottom Width, W_{be}, Slope of Weir, 0, Retention Time for Distribution Box, hrt_d, Length to Width Ratio, R_{lw}, Depth, D_{db}, Permissible Velocity Through Each Connecting Pipe, v_{pc}.
8. Compute Depth of Flow in Each Weir. Use Equation Block 7-048.
9. Compute Length, Width and Depth of Distribution Box and Depth of Flow in the Connecting Pipe. Use Equation Block 7-049.

DEFAULT VALUES

$hrt^{ur} = 6$ h, $hrt_p^{ur} = 3.5$ h, $D^{ur} = 4.0$ m, $y_{gs}^{ur} = 4.0$ m, $W_{bl}^{ur} = 0.3$ m; $v_{pc}^{ur} = 0.3$ m/s, $R_{lw}^{ur} = 4.0$.

RANGE

$hrt^{ur} = 4\text{-}6$ h, $hrt_p^{ur} = 2\text{-}5$ h, $D^{ur} = 3\text{-}6$ m, $y_{gs}^{ur} = 2\text{-}5$ m, $W_{bl}^{ur} = 0.3\text{-}0.75$ m; $v_{pc}^{ur} = 0.3\text{-}0.6$ m/s, $R_{lw}^{ur} = 2.0\text{-}8.0$.

EQUATION BLOCK 7-044

1 $V_a^{ur} = Q_a \times hrt^{ur}/24$

2 $V_p^{ur} = pf \times Q_a \times hrt_p^{ur}/24$

3 V^{ur} = Maximum of V_a^{ur} or V_p^{ur}.

4 $A^{ur} = V^{ur}/D^{ur}$

5 $d^{ur} = (A^{ur} \times 4/\pi \times N^{ur})^{0.5}$ If the Reactor is Circular

6 $W^{ur} = (A^{ur}/(N^{ur} \times R_{lw}^{ur}))^{0.5}$ If the Reactor is Rectangular in Shape

7 $L^{ur} = R_{lw}^{ur} \times W^{ur}$

UNITS

V^{ur}, m^3; L^{ur}, m; W^{ur}, m; d^{ur}, m; hrt^{ur}, h.

EQUATION BLOCK 7-045

1 $Q_{aa}^{ur} = (Q_a/86400 \times A^{ur})$

2 $N_{gs}^{ur} = L^{ur}/y_{gs}^{ur}$

3 $N_{fc}^{ur} = N_{gs}^{ur}/2$

If the Reactor is Rectangular

4 $N_{pfc}^{ur} = W^{ur}/y_{pf}^{ur}$

5 If the Reactor is Circular $\alpha = \sin^{-1}(2 \times y_{pf}^{ur} \times ni^{ur}/d^{ur})$ Where α = Angle Between Diameter and Line Joining the Centre to the End of n^{th} Channel

6 $L_c^{ur} = \cos\alpha \times D^{ur}$

7 $N_{pfc}^{ur} = L_c^{ur}/y_{pf}^{ur}$

8 $N_{pf}^{ur} = N_{fc}^{ur} \times N_{pfc}^{ur}$

9 $Q_{ap}^{ur} = (Q_a/86400 \times N_{pf}^{ur})$

10 $Q_{as}^{ur} = 0.5 \times Q_{ap}^{ur}$

UNITS

L_c^{ui}, m; Q_{aa}^{ui}, $m^3/m^2/s$; Q_{ap}^{ui}, m^3/s; Q_{as}^{ui}, m^3/s;

EQUATION BLOCK 7-046

Assuming Each Feeder Channel to be Fed from both Ends

1. $Q_{ac}^{ur} = Q_{ap}^{ui} \times N_{pfc}^{ur}/2$
2. $D_f^{ur} = [Q_{ac}^{ur}/(v_f^{ui} \times W_{bi}^{ui})]$
3. $d_{ip}^{ur} = [Q_{ap}^{ur} \times 4/(v_{pp}^{ui} \times \pi)]^{1/2}$
4. $Q_f^{ur} = cd \times \pi \times (d_{ip}^{ui})^2 \times (2 \times g \times D_f^{ui})^{1/2}/4$
5. $A_{ap}^{ur} = Q_f^{ur}/Q_{aa}^{ui}$
6. $y_h^{ui} = A_{ap}^{ui}/y_{gs}^{ui}$
7. Find Out the Slope from the Equation

$$Q_a = 1/n \times (W_{bi}^{ui} \times D_f^{ui}) \times \{(W_{bi}^{ur} \times D_f^{ur})/(W_{bi}^{ui} + 2 \times D_f^{ur})\}^{2/3} \times (\theta)^{1/2}$$

UNITS

Q_{ac}^{ur}, m^3/s; D_f^{ui}, m; d_{ip}^{ur}, m; A_{ap}^{ui}, m^2; y_h^{ui}, m;

EQUATION BLOCK 7-047

1. $L_{aa}^{ur} = \Sigma L_{ic}^{ui}$
2. $W_{aa}^{ur} = [Q_a/(L_{aa}^{ur} \times Q_{aal}^{ur} \times 24)]$

UNITS

L_{aa}^{ui}, m; W_{aa}^{ur}, m;

EQUATION BLOCK 7-048

1. In Case of Circular UASB Reactors

$$Q_q^{ur} = Q_a^{ur}/4$$

2. In Case of Rectangular UASB Reactors

$$Q_q^{ur} = Q_a^{ui}/2$$

3. Depth of Flow in Weir can be Computed from the Expression

$$Q_q^{ur} = [(W_{be}^{ur} \times D_{we}^{ui}) (W_{be}^{ur} \times D_{we}^{ur}/(W_{be}^{ur} + 2 \times D_{we}^{ur}))^{2/3} \times (\theta)^{1/2}/n$$

4. $V_{db}^{ur} = Q_a^{ur} \times hrt^{db}/2 \times 86400$

5. $A_{db}^{ur} = V_{db}^{ur}/D_{db}^{ur}$

6. $W_{db}^{ur} = [A_{db}^{ur}/R_{lwdb}^{ur}]^{1/2}$

7. $L_{db}^{ur} = W_{db}^{ur} \times R_{lwdb}^{ur}$

UNITS

D_{we}^{ur}, m; V_{db}^{ur}, m^3; A_{db}^{ur}, m^2; W_{db}^{ur}, m; L_{db}^{ur}, m;

7.21 Design of Chlorination Facility

1. Input: Average Flow, Q_a; Contact Period, T_c^{cl}; Depth of Chlorine Chamber, D^{cl}; Number of End Baffles, N_b^{cl}; Width of Influent Channel, W_{ic}^{cl}; Width W_o^{cl} & Depth of Submerged Opening, D_o^{cl}; Peaking Factor, pf;
2. Compute Volume & Length of the Chlorine Chamber. Use Equation Block 7-049.
3. Compute the Head Loss Across the Influent Structure, Weir Length at Topmost and Crest Height Use Equation Block 7-050.
4. Compute Amount of Chlorine Required, Number of Chlorinators and Chlorine Containers. Use Equation Block 7-051.
5. Display Design Flow, Number of Chlorine Chambers, Length, Width & Depth of Chlorine Chambers, Number of Baffles, Width of Influent Channel, Width & Depth of Submerged Opening, Head Loss Across Influent Structure, Length of Weir at the Crest and the Bottom.

DEFAULT VALUES

T_c^{cl} = 30 min, W^{cl} = 2.5 m, D^{cl} = 3.0 m, cl_a^{cl} = 5 mg/l, N_b^{cl} = 1, cl_c^{cl} = 450 kg.

RANGE

T_c^{cl} = 20-30 min, W^{cl} = 2.0-5.0 m, D^{cl} = 2.0 –5.0 m, cl_a^{cl} = 5-12 mg/l, N_b^{cl} = 1-5, cl_c^{cl} = 450-900 kg.

EQUATION BLOCK 7-049

1. $Q_{pe}^{cl} = pf \times Q_a/N^{cl}$
2. $V^{cl} = Q_{pe}^{cl} \times T_c^{cl}/1440$
3. $L_{lp}^{cl} = V^{cl}/(W^{cl} \times D^{cl})$
4. $L_{ch}^{cl} = L_{lp}^{cl}/(1+ N_b^{cl})$

UNITS

Q_{pe}^{cl}, m^3/d; V^{cl}, m^3; L_{lp}^{cl}, m;

EQUATION BLOCK 7-050

1. $H_t^{cl} = [Q_{pe}^{cl}/0.6 \times (2g)^{0.5} \times W_o^{cl} \times D_o^{cl} \times 86400]^2$
2. $H_{wb}^{cl} = D^{cl} - H_{wb}^{cl}$
3. $L_{wt}^{cl} = Q_{pe}^{cl}/\{1.57 \times 0.6 \times (2g)^{0.5} \times (H_{wb}^{cl})^{3/2} \times 86400\}$
4. $L_{cc}^{cl} = L_{wt}^{cl} \times (H_{wb}^{cl})^{0.5} /(0.02)^{0.5}$
5. $H_a^{cl} = (Q_{pe}^{cl}/pf \times 1.57 \times 0.6 \times (2g)^{0.5} \times 86400)^{2/3}$

UNITS

H_t^{cl}, m; H_{wb}^{cl}, m; L_{cc}^{cl}, m; H_a^{cl}, m;

EQUATION BLOCK 7-051

1. $R_{acl}^{cl} = Q_{ae}^{cl} \times cl_a^{cl}/1000$
2. $R_{pcl}^{cl} = Q_{pe}^{cl} \times cl_p^{cl}/1000$
3. $N_{cl}^{cl} = R_{pcl}^{cl}/cl_c^{cl}$

UNITS

R_{acl}^{cl}, kg/d; R_{pcl}^{cl}, kg/d;

7.22 Design of Gravity Thickener

1. Input: Sludge Flow Rate, Q_s^{th}; Mass Sludge Flow Rate, M_s^{th}; Depth of Settling Zone, D_{sz}^{th}; Hydraulic Retention Time for Blending, hrt_{bd}^{th}; Depth of Blending Tank, D_{bd}^{th}; Velocity Gradient, G^{th}; Speed of Paddle Shaft, v_{sh}^{th}; Number of Paddles, N_{pd}^{th}; Ratio of Baffle Wall to Thickener, R_{bt}^{th}; Weir Loading Rate, R_w^{th}; Velocity Through Ports, v_{pt}^{th}; Spacing of Ports, y_{pt}^{th}; Spacing of Notches, y_{nh}^{th}; Width of Effluent Launder, W_{el}^{th}.
2. Put $N^{th} = 1$ and $N_{bd}^{th} = 1$
3. Compute Quantity of Sludge, Thickener Area, Diameter and Depth of the Thickener. Use Equation Block 7-052.
4. If $d^{th} > 60$ m, $N^{th} = N^{th} + 1$
5. Compute Diameter of Blending Tank and Characteristics of Paddle Mixer (Power Requirement, Width etc.). Use Equation Block 7-053.
6. If $d_{bd}^{th} > 12$ m; $N_{bd}^{th} = N_{bd}^{th} + 1$
7. Compute Thickened Sludge and Supernatant Quality. Use Equation Block 7-054.

8. Display Design Flow, Sludge Flow, Mass of Sludge, Number of Thickeners, Diameter of Thickener, Total Side Water Depth, Depth at Centre, Solid Loading at Average Flow, Diameter of Blending Tank, Depth of Blending Tank, Diameter of Baffle Wall, Number of Ports, Diameter of Ports, Length of Weir, Width of Effluent Trough, Depth of Effluent Trough, Number of Notches, their Spacing and depth and Sludge Flow to Digester.

DEFAULT VALUES

L_s^{th} = 45 kg/m^2-d, D_{sz}^{th} = 1.5 m, hrt_{bd}^{th} = 2 h, D_{bd}^{th} = 2.5 m, G^{th} = 60, v_{sh}^{th} = 0.06 rps, N_{pd}^{th} =12, R_{bt}^{th} = 0.12, R_w^{th} = 125 m^3/m-d, v_{pt}^{th} = 0.9 m/s, y_{pt}^{th} = 0.3 m, y_{nh}^{th} = 0.20 m, W_{el}^{th} = 0.6.

RANGE

L_s^{th} = 30-60 kg/m^2-d, D_{sz}^{th} = 1.0-3.0 m, hrt_{bd}^{th} = 2-4 h, D_{bd}^{th} = 1.5-5.0 m, G^{th} = 30-85 /s, v_{sh}^{th} = 0.05-0.10 rps, N_{pd}^{th} =8-16, R_{bt}^{th} = 0.10-0.25, R_w^{th} = 125-175 m^3/m^2-d, v_{pt}^{th} = 0.75-1.2 m/s, y_{pt}^{th} = 0.25-0.40 m, y_{nh}^{th} = 0.15-0.30 m, W_{el}^{th} = 0.5-1.5.

EQUATION BLOCK 052

1. $A^{th} = M_s^{th}/(L_s^{th} \times N^{th})$
2. $L_h^{th} = Q_s^{th}/(N^{th} \times A^{th})$
3. $Q_{dl}^{th} = A^{th} \times L_{hm}^{th} - Q_s^{th}/N^{th}$.
4. $tss_b^{th} = M_s^{th} \times 1000/G_s \times 10^6 \times (Q_{dl}^{th} \times N^{th} + Q_s^{th})$
5. $d^{th} = [A^{th} \times 4/\pi]^{0.5}$
6. $P_{av}^{th} = (P_{is}^{th} + P_{es}^{th})/2$.
7. $M_{st}^{th} = \pi/4 \times (d^{th})^2 \times D^{th} \times (P_{av}^{th}/1000) \times 1.03 \times 10^6/1000$
8. $D_{tz}^{th} = M_{st}^{th}/M_s^{th}$
9. $D_t^{th} = F_b^{th} + Z_c^{th} + D_{tz}^{th}$
10. $D_{tc}^{th} = D_t^{th} + \text{Slope} \times d^{th}/2$

UNITS

A^{th}, m^2; Q_{dl}^{th}; m^3/d; d^{th}, m; D_{tz}^{th}, m; D_{tc}^{th}, m; M_s, kg/d

EQUATION BLOCK 7-053

1. $V_{bd}^{th} = Q_s^{th} \times hrt_{bd}^{th}/24$
2. $d_{bd}^{th} = [V_{bd}^{th} \times 4/\pi \times N_{bd}^{th}]^{0.5}$
3. $P_i^{th} = G_{th}^2 \times \mu_s \times V_{bd}^{th}/\eta_m$

4. $v_{sh}^{th} = 2\pi \times x_c^{th} \times \omega^{th}/60$

5. Area of Each Vertical Paddle can be Found Out from the Expression

   $P_r^{th} = \Sigma 0.5 \times C_D \times \rho \times a \times (0.75 \times v_{sh}^{th})^3$

6. $W_{pd}^{th} = A_{pd}^{th} / H_{pd}^{th}$

UNITS

V_{bd}^{th}, m^3; d_{bd}^{th}, m; P_r^{th}, W; v_{sh}^{th}, m/s; A_{pd}^{th}, m^2; ρ, kg/m^3

EQUATION BLOCK 7-054

1. $M_{sw}^{th} = M_s^{th} \times \eta$
2. $V_{ts}^{th} = M_{sw}^{th} \times 10^5/P_{av}^{th} \times N^{th} \times G_s \times 10^6$
3. $svr^{th} = \pi/4 \times (d^{th})^2 \times D_{tz}^{th} / V_{ts}^{th}$
4. $Q_{to}^{th} = Q_{st}^{th} - N^{th} X V_{ts}^{th}$
5. $tss_o^{th} = (1-\eta) \times M_s^{th} \times 10^6/Q_{to}^{th} \times 1000$

UNITS

M_{sw}^{th}, kg/d; V_{ts}^{th}, m^3/d; Q_{to}^{th}, m^3/d; tss_o^{th}, mg/l

7.23 Design of Aerobic Digester

1. Input : Sludge Flow, Q_s; Sludge Mass, M_s; VSS Loading Rate, l_{vl}^a; Mean Cell Residence Time, $bsrt^a$; Reaction Rate Constant, K; VSS Fraction, F_v^a; Depth, D^a; Solid Reduction Efficiency, η_s; Oxygen Required Per Kg of Solid Reduced, O_s^a; Oxygen Transfer Efficiency, η_{et}.
2. Put $N^a = 1$
3. Compute Volume, Depth & Diameter of Digester. Use Equation Block 7-055.
4. If $d^a > 60$ m, $N^a = N^a + 1$
5. Compute Mass of Solid Reduced, Oxygen and Air Required and Hydraulic Retention Time. Use Equation Block 7-056.
6. Display Design Flow, Volume of Digester, Number of Digesters, Diameter of Digester, Depth of Digester, Hydraulic Retention Time, Sludge Volume, Sludge Mass and VSS Loading Rate.

DEFAULT VALUES

$l_{vl}^a = 2.4$ kg - BOD/m^3-d, $F_v^a = 0.80$, $bsrt^a = 25$ d, $D^a = 3.0$ m, $hrt^a = 15$ d, $\eta_s = 0.40$, $O_s^a = 2.3$, $\eta_{et} = 0.10$, $k_d = 0.06$.

RANGE

l_{vr}^a = 1.6 - 4.8 kg - BOD/m^3-d, F_v^a = 0.70-0.90, $bsrt^a$ = 25-40 d, D^a = 2.5-5.0 m, hrt^a = 12-20 d, η_s = 0.40-0.50, O_s^a = 2.1-2.5, η_{et} = 0.08-0.14, k_d = 0.06.

EQUATION BLOCK 7-055

1. $l_v^a = F_v^a \times M_s$
2. $V_{vs}^a = l_v^a / l_{vr}^a$
3. $V_{hrt}^a = Q_s (S_{si}^a + F_{bp}^a \times B_s^a) / S_{sd}^a (K \times F_v^a + 1/bsrt^a)$
4. V^a = Maximum of These Values.
5. $d^a = [(V^a \times 4)/(\pi \times N^a \times D^a)]^{0.5}$

UNITS

L_v^a, kg/d; L_{vr}^a, kg/m^3-d; V^a, m^3; d^a, m

EQUATION BLOCK 7-056

1. $M_{sr}^a = \eta_s \times M_s$
2. $O_r^a = M_{sr}^a \times O_s^a$
3. $V_o^a = O_r^a/(1.201 \times 0.232 \times \eta_{et})$
4. $V_{om}^a = R_{av}^v \times V^a$
5. V_o^a = Maximum of These values

UNITS

M_{sr}^a, kg/d; O_r^a, kg/d; V_o^a, m^3/d;

7.24 Design of Anaerobic Digestion

1. Input: Digestion Period, t_d^{an}; VSS Fraction in Sludge, F_v^{an}; VSS Loading, l_{vr}^{an}; Depth of Digester, D^{an}; Population, P; Sludge per Capita, Q_{sp}^{an}; Yield Coefficient, y_t^{an}; Digestion Temperature, T_{dg}^{an}; Thickened Sludge Temperature, T_{st}^{an}; TVS Destruction Efficiency, η_{tvs}; Gas Storage Period, t_g^{an}; Storage Pressure, p_s^{an}; Storage Temperature, T_s^{an}; Velocity Gradient, G^{an}.

2. Compute Digester Capacity at Average Flow Condition Based on Digestion Period, Volatile Solid Loading, Population and Sludge per Capita and Volume Reduction Basis Use Equation Block 7-057.
3. Put $N^{an} = 1$
4. Compute Area, Diameter and Height of the Anaerobic Digester. Use Equation Block 7-058.
5. If $d^{an} > 38$ m, $N^{an} = N^{an} + 1$.
6. Compute Actual Solid Retention Time and Solid Loading Rate. Use Equation Block 7-059.
7. Compute Gas Production Rate and Effluent Sludge Characteristics. Use Equation Block 7-060.
8. Compute Digester Heating Requirements and Gas Storage and Compressor Requirements. Use Equation Block 7-061.
9. Display Influent Sludge Flow, Digestion Period, Number of Digesters, Diameter of Digester, Side Water Depth, Solid Loading Rate, Gas Production, Diameter of Gas Storage Sphere, Volume of Methane, Heat Required, Power of Gas Compressors, Power for Mixing and Digested Sludge Production.

DEFAULT VALUES

$t_{dg}^{an} = 14$ d, $F_v^{an} = 0.75$, $l_{vr}^{an} = 2.2$ kg/m^3-d, $D^{an} = 6$ m, $P = 10000$, $Q_{sp}^{an} = 0.03$ m^3/d, $y_t = 0.05$, $T_{dg}^{an} = 30^0$ c, $T_{st}^{an} = 20^0$ c, $\eta_{tvs} = 0.5$, $t_g^{an} = 3$ d, $p_s^{an} = 5.1$ atm, $T_s^{an} = 50^0$ c, $\mu_s = 0.00073$ N-s/m^2, $G^{an} = 85$ /s.

RANGE

$t_{dg}^{an} = 10\text{-}20$ d, $F_v^{an} = 0.70\text{-}0.85$, $l_{vr}^{an} = 1.6\text{-}6.4$ kg/m^3-d, $D^{an} = 6\text{-}12$ m, $Q_{sp}^{an} = 0.03\text{-}0.005$ m^3/d, $T_{dg}^{an} = 20\text{-}50^0$ c, $T_{st}^{an} = 15\text{-}40^0$ c, $\eta_{tvs} = 0.5\text{-}0.6$, $t_g^{an} = 3\text{-}5$ d, $p_s^{an} = 5.0\text{-}7.0$ atm, $T_s^{an} = 40\text{-}60^0$ c, $G^{an} = 70\text{-}85$ /s.

EQUATION BLOCK 7-057

1. $V_{af}^{an} = Q_s \times t_d^{an}$
2. $V_{vs}^{an} = l_v^{an}/l_{vr}^{an}$
3. $V_{cd}^{an} = P \times Q_{sp}^{an}$
4. V^{an} = Maximum Volume Obtained in the Above Calculation.

UNITS

V^{an}, m^3;

EQUATION BLOCK 7-058

1. $H_d^{an} = H_g^{an} + H_{sb}^{an} + H_{fc}^{an}$
2. $F_{av}^{an} = (D^{an} - H_d^{an})/D^{an}$
3. $V_{dr}^{an} = V^{an}/F_{av}^{an}$
4. $A^{an} = V_{dr}^{an}/(N^{an} \times D_{sw}^{an})$
5. $d^{an} = (A^{an} \times 4/\pi)^{1/2}$
6. $V_{ad}^{an} = [\pi/4 \times (d^{an})^2 \times D^{an} + 1/3 \times \pi/4 \times (d^{an})^3/2 \times \text{slope} - 1/3 \times \pi/4 \times (d^{an})^2 \times H_g^{an}] \times N^{an}$

UNITS

H_d^{an}, m; A^{an}, m^2; d^{an}, m; V_{ad}^{an}, m^3;

EQUATION BLOCK 7-059

1 $L_{sr}^{an} = M_s \times F_v^{an}/F_{av}^{an}$

2 $hrt_s^{an} = V_{ad}^{an}/Q_s$

UNITS

L_{sr}^{an}, kg.m^3-d; hrt_s^{an}, d

EQUATION BLOCK 7-060

1. $C_{ss}^{an} = M_s^{an} \times 1000/V_s$
2. $B_s = C_{ss}$ x Biodegradable Fraction(0.65) x 1.42
3. $B_p = Y \times Q_s \times \eta_u \times S_O \times 1000/(1+k_d\theta_c)$
4. $V_m = 0.35(\eta \times Q \times S_O \times 10^{-3}/1.42 \times B_p)$
5. $V_g = 1.5 \times V_m$

DIGESTED SLUDGE PRODUCTION

6 $I_v^{an} = M_s^{an} \times F_v^{an}$

7 $I_{vd}^{an} = I_v^{an} \times \eta_{vs}$

8 $S_r^{an} = (1 - F_v^{an}) \times M_s + (1 - \eta) \times I_{vd}^{an}$

9 $M_{sr}^{an} = M_s^{an} \times 100$

10 % Solids in Thickened Sludge

11 $M_{sl}^{an} = M_{sr}^{an} - V_g^{an} \times 0.86 \times 1.162$

12 Compute Digester Supernatant Solids 'S' from the Formula $S \times 10^6/4000 + (S_{rd}^{an} - S)/0.05 = M_{sl}^{an}$

13 $Q_{sf}^{an} = S \times 1000/4000$

UNITS

C_{ss}^{an}, mg/l; B_s^{an}, mg/l; B_p^{an}, mg/l; V_m^{an}, m^3/d; V_g^{an}, m^3/d

EQUATION BLOCK 7-061

1. $H_r^{an} = M_s^{an} \times 4200 \times (T_d^{an} - T_s^{an})$
2. $A_{hl}^{an} = A_{rf}^{an} + A_{sw}^{an} + A_{bt}^{an}$
3. $A_{rf}^{an} = \pi \times d^{an} \times [(d^{an}/2)^2 + C_r^{an}]^{0.5}/2$
4. $A_{sw}^{an} = \pi \times d^{an} \times H^{an}$
5. $A_{bt}^{an} = \pi \times d^{an} \times [(d^{an}/2)^2 + (d^{an} \times Slope/2)^2]^{0.5}/2$
6. $H_l^{an} = A_{hl}^{an} \times H_{tc}^{an} \times 86400 \times T_d^{an}$
7. $H_t^{an} - H_r^{an} + H_l^{an}$

GAS STORAGE & COMPRESSOR REQUIREMENT

8. $V_{tg}^{an} = V_g^{an} \times t_g^{an}$
9. $V_{sg}^{an} = V_{tg}^{an} \times (273 + T_s^{an})/(p_s^{an} \times 273)$
10. $d_s^{an} = [V_s^{an} \times 6/\pi]^{1/3}$
11. $w_{gc}^{an} = 2 \times w_{gp}/86400$
12. $P_c^{an} = [w_g^{an} \times 8.314 \times (273 + T_d^{an})]$

UNITS

A_{rf}^{an}, m^2; A_{bt}^{an}, m^2; A_{sw}^{an}, m^2; V_{tg}^{an}, m^3; V_s^{an}, m^3; w_g^{an}, kg/d;

7.25 Design of Sludge Drying Beds

1. Input: Sludge Solids, M_s; Sludge Loading Rate, L_{sl}^{sdb}; Length of Drying Bed, L^{sdb}, Width of Drying Bed, W^{sdb}; % Solids in Sludge, P_s^{sdb}; Depth of Gravel, D_g^{sdb}; Depth of Sand, D_{ss}^{sdb}.
2. Compute Area, Number of Drying Beds and Depth of Drying Bed Required. Use Equation Block 7-062.
3. Display Sludge Mass, Sludge Volume, Number of Drying Beds, Length, Width and Depth of Drying Bed.

DEFAULT VALUES

L_{sl}^{sdb} = 100 kg Solid/m^2/a, L^{sdb} = 30 m, W^{sdb} = 6.0 m, P_s^{sdb} = 6.0, D_g^{sdb} = 0.25 m, D_{ss}^{sdb} = 0.20 m.

RANGE

L_{sl}^{sdb} = 100-300 kg Solid/m^2/a, L^{sdb} = 30-45 m, W^{sdb} = 6.0-8.0 m, P_s^{sdb} = 6.0-8.0, D_g^{sdb} = 0.15-0.30 m, D_{ss}^{sdb} = 0.20-0.30 m.

EQUATION BLOCK 7-062

1. $A^{sdb} = M_s \times 365/L_{sl}^{sdb}$
2. $N^{sdb} = \mathrm{Int}[A^{sdb}/(L^{sdb} \times W^{sdb})]$
3. $V^{sdb} = M_s \times 100/P_s^{sdb} \times 1/1.005 \times 1/1000$
4. $D^{sdh} = [(V^{sdb} \times 365)/(N^{sdb} \times L^{sdb} \times W^{sdb} \times 8)]$
5. $D_t^{sdb} = D^{sdb} + D_g^{sdb} + D_s^{sdb}$

UNITS

A^{sdb}, m^2; V^{sdb}, m^3/d, D^{sdb}, m;

7.26 Design of Filter Press

1. Input: Sludge Solids, M_s; Lime Dose/Sludge Solids, L_{ds}^{fpr}; Polymer/Sludge Solids, P_{ds}^{fpr}; Operating Time, T_h^{fpr}; Operating Days, T_d^{fpr}; Rate of Filtration, R_f^{fpr}.
2. Compute Total Solids Processed per Hour and Required Filter Area. Use Equation Block 7-063.
3. Display Total Sludge Solids, Lime Requirement, Polymer Requirement, Operating Time, Operating Days, Area of Filter Press.

DEFAULT VALUES

$L_{ds}^{fpr} = 0.05$, $P_{ds}^{fpr} = 0.02$, $T_h^{fpr} = 8$ h, $T_d^{fpr} = 5$ d/Week, $R_f^{fpr} = 10$ kg/m^2-hr.

RANGE

$L_{ds}^{fpr} = 0.04\text{-}0.06$, $P_{ds}^{fpr} = 0.02\text{-}0.03$, $T_h^{fpr} = 8\text{-}12$ h, $T_d^{fpr} = 5\text{-}7$ d/Week, $R_f^{fpr} = 10\text{-}12$ kg/m^2-hr.

EQUATION BLOCK 7-063

1. $M_{sp}^{fpr} = [M_s^{fpr} \times 7/T_d^{fpr}]$
2. $L_r^{fpr} = L_{ds}^{fpr} \times M_{sp}^{fpr}$
3. $R_{py}^{fpr} = P_{ds}^{fpr} \times M_{sp}^{fpr}$
4. $M_{ts}^{fpr} = M_{sp}^{fpr} + L_r^{fpr} + R_{py}^{fpr}$
5. $T_{th}^{fpr} = M_{ts}^{fpr}/(T_h^{fpr} \times 24)$
6. $A^{fpr} = T_{th}^{fpr}/R_f^{fpr}$

UNITS

M_{sp}^{fpr}, kg/d; L_r^{fpr}, kg/d; R_{py}^{fpr}, kg/d; M_{ts}^{fpr}, kg/d; A^{fpr}, m^2.

8 Advice – I: Air Pollution Control

The basic purpose of air pollution control is to limit the discharge of air pollutants to atmosphere, which create the health hazard to humans and affect vegetation and animal life adversely. The principle components included in this system are – design of local exhaust ventilation system to capture the emissions from the discharge point, design of emission control equipment to treat or remove the particulate and gaseous emissions and air dispersion modeling to study the impact of emissions on surrounding.

8.1 Local Exhaust Ventilation System

The local exhaust ventilation system includes design of hoods, duct and fans. Primarily these units are used to collect the emissions from the source through hoods and convey it to the stacks or emission control equipment by the help of fans. These options can be further elaborated as –

Hoods: Hoods are devices used to ventilate process equipment by capturing emissions of heat of air contaminants, which are then conveyed through exhaust system ductwork to a more convenient discharge point or to a air pollution control equipment. The quantity of air required, to capture and convey the air contaminant depends upon the size and shape of the hood, its position relative to the point of emission and the nature and quantity of the air contaminant.

In hoods when significant quantities of heat are transferred to the surrounding air by conduction and convection, a thermal draft is created that may cause a rising air

current with considerable velocity. The higher the column rises, the larger it becomes and the more diluted with ambient air.

Ducts: Ducts are used as a conduit to convey the air contaminants intercepted at hoods to air control equipment or exhaust point, whatever the case may be.

Fans: Fans are used to move air from one point to another. In the control of air pollution, the fan imparts movement to air mass and conveys the air contaminants from the source of generation to a control device in which air contaminants are separated and collected, allowing clean air to be exhausted to the atmosphere.

8.1.1 Hoods

Hoods are further classified as – Hoods for Cold Processes and Hoods for Hot Processes. Design of hoods for hot processes generally take into account the huge amount of heat liberated during the process. Hoods for cold processes do not take into consideration any such factor.

Hoods for Hot Processes: In hoods when significant quantities of heat are transferred to the surrounding air by conduction and convection, a thermal draft is created that may cause a rising air current with considerable velocity. The higher the column rises, the larger it becomes and the more diluted with ambient air. Design of this system take into account the rising air velocity and the dilution of emission with ambient air.

Hoods for Cold Processes: Design of such systems include the determination of exhaust rate based on velocity and area of hood face. These velocities have been recommended based on experience and vary considerably from industry to industry.

8.2 Emission Control

The pollutants emitted from the sources are either particulate matters or gaseous particles. Each of these pollutants needs different type of treatment. In this option, the emission control has been broadly categorized into two groups –

Equipment that controls particulate matters and other, which control the gaseous emissions.

Particulate Control: Particulate control in air pollution means the separation of suspended particles, aerosols etc. which can be removed from the air stream by applying the physical forces.

Gaseous Control: Gaseous pollutant control results in the removal of gases like SO_2, NO_x, CO etc. which otherwise have created nuisance adversely affecting human and animal life, vegetation if discharged untreated to the atmosphere.

8.2.1 Particulate Control

Particulate control equipment include settling chambers, cyclones, scrubbers, electrostatic precipitator and fabric filters which employ one or combination of physical forces to remove the suspended particulate matters in the gas stream.

Settling Chambers: The settling chamber basically consists of an expansion chamber in which the particle velocity is reduced to such an extent that the particle may settle out under the action of gravity. Its use in the industry is limited to the removal of the large sized particles (greater than 40 μm). Gravity settlers are usually constructed in the form of a long, horizontal parallelepiped with suitable inlet and outlets. There are basically two types of gravity settlers – the simple expansion chamber and the multiple tray settling chambers. In the multiple tray settling chambers, the detention time is low due to shallower depth and collection efficiency is very high due to large surface area.

Cyclone Chambers: A cyclone chamber is an inertial separator without moving parts, which separate particulate matter from a carrier gas by transforming the velocity of an inlet stream into a double vortex confined within the cyclone. In the double vortex the entering gas spirals downward at the outside and spirals upward at the inside of the cyclone outlet. The particulate matters, because of their inertia, tend to move towards the outside wall, from which they are led to a receiver.

The construction of inertial separators is relatively simple, and initial costs and maintenance costs are generally lower than for most other types of dust collectors. Collection efficiencies, however, are not very high. They are best suited for 15-40 μm particles but are more often used as pre-cleaners for other size range particles also.

Wet Scrubbers: In wet scrubbers, a liquid, usually water is used to capture particulate dust or to increase the size of aerosols. In either case the resulting increased size facilitates the removal of the contaminant from the gas stream. Fine particles, both liquid and solid ranging from 0.1 to 20 μm can be effectively removed from a gas stream by wet scrubbers. The major mechanisms involved with particle collection are inertial impaction, direct interception, diffusion, electrostatic forces, gravitational forces and condensation etc. The major problem attached with scrubber is the disposal of wet sludge.

Fabric Filters: A filter generally is any porous structure composed of granular or fibrous material which tends to retain the particulate as the carrier gas passes through the voids of the filter. The filter is constructed of any material compatible with the carrier gas and particulate matter, and may be arranged in deep beds, mats or fabric. The filter is capable of providing high efficiencies for particles as small as 0.5 μm and will remove a substantial quantity of those particles as small as 0.01 μm.

Electrostatic Precipitator: In electrostatic precipitator, particulate and aerosols collection is based on the mutual attraction between particles of an electric charge and a collecting electrode of opposite polarity. In this apparatus, particles are given an electric charge by forcing them to pass through a direct current corona a region in which gaseous ions flow. The electric field that forces the charged particles to the walls comes from electrodes maintained at high d. c. voltage in the center of the flow lane. The removal of collected particles is accomplished by knocking them loose from the plates allowing the collected layer of particles to slid down into a hooper from which they are evacuated.

The advantages of ESP include capacity to handle large gas volumes, high collection efficiencies even for sub-micron size particles, low energy consumption and ability to operate with relatively high temperature gases.

The relative ratings considering various aspects of the "particulate control" option, as included in the "comparison" option, are presented in Table 8.1.

Table 8.1: Relative Ratings of Various Particulate Control Equipment

	Description	Settling Chamber	Cyclones	Scrubber	Fabric Filter	Electrostatic Precipitator
1.	Capital cost	6	8	6	6	10
2.	Maintenance cost	4	8	8	10	10
3.	Ability to remove high pollutant load	C	C	C	D	C
4.	Skilled supervision required	4	4	6	8	8
5.	Area required	10	6	6	4	4
6.	Extent of use	4	6	8	8	8
7.	Power requirement	4	4	4	6	10
8.	Removal efficiency	4	6	6	10	8
9.	Removable particle size, μm	> 40	15-40	0.1-20	0.5	<0.01

8.2.2 Gaseous Pollution Control

Absorption: Absorption involves bringing the dirty effluent gas into contact with the scrubbing liquid and subsequently separating the cleaned gas from the contaminated liquid. It provides thorough contact between the gas and liquid solvent so that inter-phase diffusion occurs. It is essentially a mass transfer or diffusion operation characterized by a transfer of one substance through another, usually on a molecular scale. The mass transfer process may be considered as the result of a concentration difference driving force, the diffusing substance moving from a place of relatively high to one of relatively low concentration.

The advantages of absorption proccss includes relatively low pressure drop, capable of achieving relatively high mass transfer efficiencies, low capital cost, small space requirement, and ability to collect particulate as well as gases. The

disadvantages include water disposal problem, plugging of bed by particulate deposition, high maintenance cost and sensitivity to temperature.

Adsorption: Adsorption is a separation process based on the ability of certain solids to remove gaseous components preferentially from a flow stream. The pollutant gas or vapor molecules present in the waste stream collect on the surface of the solid material. The solid adsorbing medium is frequently termed as adsorbent, while the gas or vapor adsorbed is called the adsorbate. This process takes place due to the unbalance of forces at the surface of the adsorbent.

Adsorption process is a particularly useful technique when the pollutant gas is non combustible or have a very dilute concentration, and/or is sufficiently valuable to recover. The advantages include product recovery, excellent control, no disposal problem, capability of systems to provide fully automatic, unattended operation and high removal efficiency. The disadvantages of this process are progressive deterioration of adsorbent, high capital cost, plugging of bed, high stream requirement and expensive maintenance.

Condensation: It is used in few cases to control air contamination. It is the process of converting a gas to a liquid by sufficiently lowering its temperature and/or its pressure. When a hot gas stream contacts a cooler medium, heat is transferred from the hot gases to the cooler medium. As the temperature of the gas stream is decreased, the average kinetic energy of the gas stream is reduced. Ultimately the gas molecules are slowed down and crowded so closely together that the attractive forces between the molecules cause them to condense to a liquid.

Condensers are typically used as a pre-treatment devices, as they cannot achieve the collection efficiency required by industry using ordinarily available cooling medium.

Incineration: Incineration is a controlled oxidation process used for destruction of vaporous volatile organic compounds or some toxic gaseous emissions from industrial waste gases. In the process the VOC content of waste gases react at high temperature with oxygen to form carbon dioxide and water, while liberating heat. The combustion performance depends upon temperature, residence time and turbulence. It is

frequently used in situations where the volume flow rate of waste gas from a process is large but the level of contaminant gas is small.

Incineration process is simple in operation and capable of achieving high destruction efficiency of organic contaminants. The disadvantages include high operating cost, potential for flash back and subsequent explosion hazard.

The relative ratings considering various aspects of the "gaseous emission control" option, as included in the "comparison" option, are presented in Table 8.2.

Table 8.2: Relative Ratings of Various Gaseous Pollutant Control Equipments

	Description	Absorption	Adsorption	Condensation	Incineration
1.	Capital cost	6	6	4	8
2.	Maintenance cost	8	8	4	6
3.	Ability to remove high pollutant load	6	6	8	10
4.	Skilled supervision reqd.	6	6	6	4
5.	Area required	6	6	4	4
6.	Extent of use	6	4	6	8
7.	Power requirement	6	4	6	10
8.	Removal efficiency	6	6	6	8

8.3 Atmospheric Dispersion of Pollutant

Choose this option for modeling the impact of selected gaseous emissions from the source concerned. It helps in predicting ambient concentrations of pollutant in the urban areas on the basis of dispersion from sources within the region and helps in maintaining the federal ambient air quality standards.

9 Advice – II: Water Treatment System

The basic purpose of water treatment system is to treat raw water from natural water bodies such as rivers, reservoirs (surface, underground), lakes etc. to such an extent that it can be used for drinking purposes. The unit operations and devices used for this are displayed as different available options of the water treatment system menu. Following is a brief note on each of these options.

Aeration: Select this option for aeration of water for (i) to add oxygen to water for imparting freshness, (ii) to expel Carbon Dioxide, Hydrogen Sulfide and volatile substances mainly organic causing taste and odour, (iii) to precipitate impurities like Iron and Manganese, etc.

Settling: Select this option before or after coagulation and precipitation to separate the suspended solids from water. Settling is used to remove readily settling sediments such as sand and silt, coagulated impurities such as color and turbidity and precipitated impurities such as hardness and Iron.

Feeding Tank: Select this option for design of dosing tanks used for storing chemical feed in the form of solution and mixing into water.

Rapid Mix: Select this option for rapidly and uniformly mixing coagulants and chemicals throughout mass of water. This helps in formation of micro-flocs and results in proper utilization of a chemical coagulant preventing localization of concentration and premature formation of hydroxides which leads to less effective utilization of the coagulant. The source of power for rapid mixing are gravitational,

mechanical and pneumatic. Use this option before flocculation, clari-flocculation, softening and/or disinfection.

Flocculation: Use this option for design of flocculation units. Select this option before softening, filtration and disinfection. In flocculation the hydrodynamic process of slow mixing results in formation of large and readily settleable flocs by bringing the finely divided matter into contact with the micro-flocs formed during rapid mixing. These can be subsequently removed in settling tanks.

Clari-flocculation: Use this option when coagulation, flocculation and clarification/settling operations are to be achieved in one unit.

Softening: Use this option to remove hardness. The purpose of softening is to reduce the soap consuming properties, reduce scaling problems in heaters and geysers and improve palatably. When hardness is less than 150 mg/l softening for domestic purposes is usually not justified. Options available are chemical and ion exchange. After this option choose rapid mix, flocculation, settling and/or disinfection.

Filtration: Choose this option for design of filtration units from the options slow sand, high rate and pressure. Use this option for separating out suspended and colloidal impurities from water by a passage through a porous bed. It is employed for treatment of water to effectively remove turbidity, color, microorganisms, precipitated hardness from chemically softened waters and precipitated Iron and Manganese from aerated waters. Select this option after flocculation and settling or softening and settling. Choose disinfection after this option.

Disinfection: Choose this option for design of disinfection units. Select this option for ensuring that pathogens and other microorganisms are inactivated. Bacteria, Viruses and Amoebic Cysts constitute the three main types of human enteric pathogens and effective disinfection is aimed at destruction or inactivation of these and other pathogens such as helminths responsible for water borne diseases. The need for disinfection in ensuring protection against transmission of water borne diseases cannot be over emphasized and its inclusion as one of the water treatment process is

considered necessary. Use this option for pre (before coagulation-flocculation or filtration) and post disinfection (last unit operation in the water treatment).

Advance Processes: Use this option for production of ultra pure water and treatment of saline water. This option should be chosen after each of above options.

9.1 Aeration

Diffused Aeration: Use this option for design of diffused aeration system with nozzle diffusers. This unit consists of nozzles and pipes in a basin in which compressed air is injected to rise through water being aerated. As the rising bubbles of air have a lower average velocity than the falling of drops, this unit provides a longer aeration period than the cascade type for the same head loss. These have higher initial costs and require greater recurring expenditure. They require less space than spray aerators and cold weather working problems are not encountered. It is less popular in water treatment plant in comparison to other options.

Cascade Aeration: Use this option for design of cascade aerator in which water is allowed to flow downwards in a series of falls to produce turbulence. It adds to the beauty of plant. Head loss is greater than other options. In cold climates these aerators must be housed width adequate provision for ventilation. Corrosion and slime problem may be encountered in aerated water.

Spray Aeration: Use this option for design of spray aeration system in which water is sprayed through nozzles upward into the atmosphere in the form of fountain and broken up into either mist or droplets. Water is directed at a slight inclination to the vertical. The installation consists of trays and fixed nozzles on a pipe grid with necessary outlet arrangements.

The comparative performance and relative ratings considering various aspects of the "aeration" option as included in the "performance" and "comparison" advice options, are presented in Tables 9.1 and 9.2 respectively.

Table 9.1: Comparative Performance of the Three Aeration Processes

	Description	Diffused	Cascade	Spray
1.	Carbon Dioxide removal %	40-75	20-45	70-90
2.	Hydrogen Sulfide removal %	50-80	20-35	90-99
3.	Volatile organic removal	NA	NA	NA
4.	Precipitation of Iron	NA	NA	NA
5.	Pressure required at nozzles (m of water)	5	N/A	7
6.	Precipitation of Manganese	NA	NA	NA
7.	Aerator area, m^2/KLD	N/A	0.50-0.65	0.00125-0.00375
8.	Air required m^3/KL	0.6-1.5	N/A	N/A
9.	Head loss (m of water)	N/A	0.5-0.30	8-10
10	Power required W/KL	3-10	N/A	N/A

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.2: Relative Ratings of the Three Aeration Processes

	Description	Diffused	Cascade	Spray
1.	Gas Transfer Efficiency	6	4	8
2.	Efficiency in cold climate	8	2	4
3.	Freedom from manufacturers patents	E	B	D
4.	Skilled person requirement	4-6	2	4-6
5.	Initial cost	8	4-6	6-8
6.	Maintenance cost	8	2-4	4-6
7.	Extent of use	2	6	8

Note: For rating levels and abbreviations please refer to section 4.4.

9.2 Settling

High Rate: Use this option for design of tube settlers and plate settlers. These have higher efficiency. Use of high rate settlers can reduce detention time to few minutes. These units achieve better efficiency and economy in space as well as cost.

Conventional: Use this option for design of conventional settling like rectangular and circular settling tanks. In these tanks direction of flow is substantially horizontal. Sludge is removed by mechanical scrapers.

The comparative performance and relative ratings considering various aspects of the "settling" option, as included in the "performance" and "comparison" advice options, are presented in Tables 9.3 and 9.4 respectively.

Table 9.3: Comparative Performance of the Conventional and High Rate Settling Units

	Description	Conventional	High Rate
1.	Hydraulic retention time, (hours)	1-8	0.2-0.8
2.	Weir loading (m/d)	150-300	600-1200
3.	Surface Overflow Rate (m/d)	15-60	96-144
4.	Depth of Tank (m)	3-7	3-10

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.4: Relative Ratings of the Conventional and High Rate Settling Units

	Description	Conventional	High Rate
1.	Freedom from streaming and overturn	8	4
2.	Efficiency with heavily silted water	8	4
3.	Efficiency in variable influent quality	8	4-6
4.	Effectiveness with algae	C	E
5.	Suitability for Iron removal	C	E
6.	Suitability for lime softening	C	E
7.	Effectiveness on small scale	D	B
8.	Effectiveness on big works	B	B
9.	Advantageous use of land	E	B
10.	Ease of cleaning	B	E
11.	Freedom from manufacturers patents	B	E
12.	Skilled Person requirement	4	8
13.	Overall cost	4	6
14.	Extent of use	8	2

Note: For rating levels and abbreviations please refer to section 4.4.

9.2.1 High Rate Settlers

Tube Settler: Use this option for design of tube settlers to reduce the effective surface area and hydraulic retention time. These provide excellent clarification for detention

time less than 10 minutes. These units consist of tube settlers made of prefabricated thin black sheets 1 m long of PVC, timber, asbestos cement etc.

Plate Settler: Use this option for design of plate settlers units. Parallel plates are usually introduced to enhance the efficiency of existing conventional rectangular settling basins. As such both tube and plate settlers are equivalent options.

The comparative performance and relative ratings considering various aspects of the "high rate settlers" option, as included in the "performance" and "comparison" advice options, are presented in Tables 9.5 and 9.6 respectively.

Table 9.5: Comparative Performance of the Tube and Plate Settlers

	Description	Tubes	Plates
1.	HRT (hour)	0.2-0.8	0.5-1.0
2.	Weir Loading (m/d)	800-1200	600-1000
3.	Surface overflow rate (m/d)	100-144	96-120
4.	Inclination from horizontal	5-60	5-60
5.	Flow Velocity through tubes/plates (m/s)	0.003-0.006	0.003-0.005

Note: For rating levels and abbreviations please refer to section 4.4.

9.6: Relative Ratings of the Tube and Plate Settler

	Description	Tube	Plate
1.	Freedom from streaming and overturn	4	4
2.	Efficiency with heavily silted water	4	4
3.	Efficiency in variable influent quality	6	8
4.	Effectiveness with algae	E	E
5.	Suitability for Iron removal	D	D
6.	Suitability for lime softening	D	C
7.	Effectiveness on small scale	B	B
8.	Effectiveness on big works	B	B
9.	Advantageous use of land	B	B
10.	Ease of cleaning	E	D
11.	Skilled Person requirement	6	8
12.	Overall cost	6	4

Note: For rating levels and abbreviations please refer to section 4.4.

9.2.2 Conventional Settlers

Rectangular Settling Tank: Use this option for design of rectangular settling tanks. It is little difficult to construct and analyze structurally. Sludge scrapers require arrangement of adjustable arms to reach corner points of tank. Multiple unit construction may lead to economy due to common walls. For same area it gives less weir loading than circular shaped settling tanks.

Circular Settling Tank: Use this option for design of circular settling tanks. It is easy to construct and analyze structurally. Simple sludge scrapers are required. May not be economical in case multiple units are required. Options available are radial flow and circumferential flow.

The comparative performance and relative ratings considering various aspects of the "conventional settlers" option, as included in the "performance" and "comparison" advice options, are presented in Tables 9.7 and 9.8 respectively.

Table 9.7: Comparative Performance of the Rectangular and Circular Settling Tanks

	Description	Rectangular	Circular
1.	Hydraulic retention time, h	3-8	1-2.5
2.	Weir Loading (m/d)	150-200	150-600
3.	Surface overflow rate	10-60	25-75
4	Depth of Tank (m)	4-7	3-5
5.	Length/Diameter of tank	5-100	5-60
6.	Length to Width Ratio	3-5	N/A

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.8: Relative Ratings of the Rectangular and Circular Settling Tanks

	Description	Rectangular	Circular
1.	Freedom from streaming and overturn	8	8
2.	Efficiency with heavily silted water	8	6
3.	Efficiency in variable influent quality	8	6
4.	Effectiveness with algae	C	B
5.	Suitability for pre-sedimentation	B	C

6.	Suitability for lime softening	C	B
7.	Effectiveness on small scale	D	D
8.	Effectiveness on big works	B	B
9.	Advantageous use of land	D	C
10.	Ease of cleaning	B	C
11.	Freedom from manufacturers patents	B	C
12.	Skilled Person requirement	4	6
13.	Overall cost	6	8
14.	Extent of use	8	6

Note: For rating levels and abbreviations please refer to section 4.4.

Circular settling tanks can be of two types depending upon the flow pattern as follow.

(i) Radial Flow Settling Tank: Use this option for design of radial flow circular settling tanks. In this unit influent is fed through center and flow approaches horizontal. Effluent is collected by effluent launder at circumference.

(ii) Circumferential Flow Settling Tank: Use this option for design of circumferential flow circular settling tanks. In this unit influent enters through bottom of rim or circumference of the tank and effluent is collected at top of rim or circumference of tank. The flow approaches to vertical flow.

The comparative performance and relative ratings considering various aspects of the "circular settling tank" option, as included in the "performance" and "comparison" advice options are presented in Tables 9.9 and 9.10 respectively.

Table 9.9: Comparative Performance of the Radial and Circumferential Flow Circular Settling Tanks

	Description	Radial Flow	Circumferential Flow
1.	Hydraulic retention time (hr)	2-2.5	1-1.5
2.	Weir loading (m^3/d)	200-500	300-600
3.	Surface overflow rate (m/d)	25-75	40-50

4.	Depth of tank (m)	4-5	4-6
5.	Diameter of tank (m)	5-60	5-30
6.	Diameter to depth ratio	1-20	1-10

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.10: Relative Ratings of the Radial and Circumferential Flow Circular Settling Tanks

	Description	Radial Flow	Circumferential Flow
1.	Freedom from streaming and overturn	6	4
2.	Efficiency with heavily silted water	6	4
3.	Efficiency in variable influent quality	6	6
4.	Effectiveness with algae	D	B
5.	Suitability for pre-sedimentation	C	D
6.	Suitability for lime softening	C	C
7.	Effectiveness on small scale	D	D
8.	Effectiveness on big works	B	B
9.	Advantageous use of land	D	D
10.	Ease of cleaning	B	C
11.	Freedom from manufacturers patents	C	C
12.	Skilled Person requirement	4	6
13.	Overall cost	6	8
14.	Extent of use	6	4

Note: For rating levels and abbreviations please refer to section 4.4.

9.3 Rapid Mix Unit

Mechanical Rapid Mix Unit: Use this option for selecting mechanical units for rapid mixing. These are most commonly used for rapid mixing. The mechanical units are efficient as they have little head loss and are unaffected by volume of flow or flow variations. These are best suited for plants where head loss through the plant is to be

conserved as much as possible and where the flow exceeds 300 m^3/h. However, these units require regular maintenance and consume more energy.

Non Mechanical Rapid Mix Unit: Use this option for selecting hydraulic jump for baffled channels for rapid mixing. These units are simple to construct but do not give flexibility. No mechanical equipment is needed to operate and maintain. In these units head loss is appreciable. These are relatively less suitable because they have excellent plug flow and poor mixed flow characteristics. In these devices, the required turbulence is obtained from the flow of water under gravity or pressure.

The Comparative performance and relative ratings considering various aspects of the "rapid mix units" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.11 and 9.12 respectively.

Table 9.11: Comparative Performance of the Mechanical and Non-mechanical Rapid Mix Units

	Description	Mechanical	Non-mechanical
1.	Hydraulic retention time, s	10-120	10-100
2.	Velocity gradient, /s	750-5000	800-4000
3.	Power required, $w/m^3/h$	1-3	N/A
4.	Head loss, m of water	N/A	0.3-5.0

Note: For rating levels and abbreviations please refer to section 4.4.

9.12: Relative Ratings of the Mechanical and Non-mechanical Rapid Mix Units

	Description	Mechanical	Non-Mechanical
1.	Efficiency with variable influent quality	10	4
2.	Effectiveness on small scale	B	B
3.	Effectiveness on big works	B	D
4.	Advantageous use of land	B	E
5.	Freedom from manufacturers patents	E	A
6.	Skilled person requirement	8	4
7.	Overall cost	8	4
8.	Extent of use	8	4

Note: For rating levels and abbreviations please refer to section 4.4.

9.3.1 Mechanical Rapid Mix Unit

Jet Injector: Use this option for selecting jet injector for rapid mixing. In this unit chemical is introduced through nozzles/holes at a pressure in opposite direction of flow. It is less used due to plugging of orfices and non flexibility of the unit.

Inline Blender: Use this option for selecting inline blender for rapid mixing. These units were developed for a very rapid instantaneous mixing of chemicals with a minimum of short circuiting. These are less expensive than turbine type. Most suitable for adsorption destabilization type colloidal reactions.

Turbine Type Rapid Mix Unit: Use this option for selecting turbine type unit for mixing. These units comprise of flat beds attached to a shaft rotating at considerable RPM (100 RPM) which generates turbulence and current to mix the chemicals instantaneously. This unit is more common for mixing chemicals and coagulants. Most suitable for sweep coagulation reactions.

The Comparative performance and relative ratings considering various aspects of the "mechanical rapid mix units" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.13 and 9.14 respectively.

Table 9.13: Comparative Performance of Jet Injector, Inline Blender and Turbine Type Rapid Mix Units

	Description	Jet	Inline	Turbine
1.	Velocity gradient, /s	750-1000	3000-5000	700-1000
2.	Detention time, s			50-120
3.	Shaft speed, rpm	N/A	NA	150-1500

Note: For rating levels and abbreviations please refer to section 4.4.

9.14: Relative ratings of Jet Injector, Inline Blender and Turbine Type Rapid Mix Units

	Description	Jet	Inline	Turbine
1.	Area requirement	4	8	10
2.	Power requirement	6	6	8
3.	Extent of use	6	6	8
4.	Freedom from manufacturers patents	E	E	E
5.	Head loss	8	6	6
6.	Performance in variable flow	D	B	B
7.	Overall cost	4	6	8

Note: For rating levels and abbreviations please refer to section 4.4.

9.3.2 Non Mechanical Rapid Mix Unit

Baffled Rapid Mix Unit: Use this option for selecting baffled units for mixing. Baffle plates can be of steel, wood or concrete. Velocity gradients are purposely intensified by enforced changes in the direction of flow. It is a simple system but is not flexible and involves much loss of head. The detention period is also restricted as otherwise long channels are required.

Hydraulic Rapid Mix Unit: Choose this option for design of hydraulic jump as mixing unit. In this unit mixing is achieved by a combination of a chute followed by a channel with or without sill. Loss of head is appreciable and detention time is also very low. This unit though relatively inflexible, is simple and can be used as a standby in large plants to the mechanical mixer while for small plants, this can serve directly as the main unit.

The Comparative performance and relative ratings considering various aspects of the "non-mechanical rapid mix units" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.15 and 9.16 respectively.

Table 9.15: Comparative Performance of Baffled and Hydraulic Jump Type Rapid Mix Units

	Description	Baffled	Hydraulic Jump
1.	HRT, sec	10-30	3-10
2.	Velocity gradient, /s	700-1000	600-1200
3.	Flow through velocity, m/s	0.5-1.5	3-4
4.	Head loss, m of water	0.5-2.5	0.3-0.6

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.16: Relative Ratings of Baffled and Hydraulic Jump Type Rapid Mix Units

	Description	Baffled	Hydraulic Jump
1.	Efficiency with variable influent quality	2	2
2.	Effectiveness on small scale	B	B
3.	Effectiveness on big works	D	E
4.	Advantageous use of land	E	C
5.	Freedom from manufacturers patents	A	A
6.	Skilled person requirement	4	6
7.	Overall cost	8	6
8.	Extent of use	6	4

Note: For rating levels and abbreviations please refer to section 4.4.

Baffled rapid mix units can be of two types depending upon the orientation of the baffles as follows.

Vertical Baffled Rapid Mix Unit: Use this option for selecting vertical baffled unit for rapid mixing. Velocity gradients are purposely intensified by enforced changes in the direction of flow upwards and downwards. In this unit a homogeneous mixture of the suspended particle is maintained due to alternate rise and fall of water, which prevents deposition of sludge.

Horizontal Baffled Rapid Mix Unit: Use this option for selecting horizontal baffled unit for rapid mixing. It consists of series of baffles around the ends of which the flowing water is reversed in direction, thus causing turbulence and agitation at each point of reversed flow. Proper scouring arrangements have to be made in this unit to prevent deposition of sludge.

The Comparative performance and relative ratings considering various aspects of the "baffled rapid mix units" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.11 and 9.12 respectively.

Table 9.17: Comparative Performance of Vertical and Horizontal Baffled Rapid Mix Units

	Description	Vertical	Horizontal
1.	HRT, sec	10-30	10-30
2.	Velocity gradient, /s	700-1000	800-1200
3.	Flow through velocity, m/s	0.5-1.5	0.5-1.5
4.	Head loss, m of water	0.5-2.5	0.5-2.5

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.18: Relative Ratings of Vertical and Horizontal Baffled Rapid Mix Units

	Description	Vertical	Horizontal
1.	Efficiency with variable influent quality	4	4
2.	Effectiveness on small scale	B	B
3.	Effectiveness on big works	D	D
4.	Advantageous use of land	E	E
5.	Freedom from manufacturers patents	A	A
6.	Skilled person requirement	6	6
7.	Overall cost	6	6
8.	Extent of use	4	8

Note: For rating levels and abbreviations please refer to section 4.4.

9.4 Flocculation

Mechanical Flocculation: Mechanical flocculation units include inline blender, paddle type and flat blade turbine. These are flexible units since the speed of mechanical blades or paddles can be adjusted to suit the variations in flow, temperature and silt conditions. These units consist of revolving paddles with horizontal or vertical shaft. The paddles are driven by motor either of constant or multiple speed operating through a gear type reducer or drive belt chains.

Non Mechanical Flocculation: Use this option for selecting non-mechanical flocculation units, baffled and gravity flocculators. These units lack flexibility since the system can be designed for maximum efficiency only at one rate of flow and at one temperature.

The Comparative performance and relative ratings considering various aspects of the "flocculation" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.19 and 9.20 respectively.

Table 9.19: Comparative Performance of Mechanical and Non-mechanical Flocculation Units

	Description	Mechanical	Non-mechanical
1.	HRT, sec	10-60	10-600
2.	Velocity gradient, /s	10-100	20-75
3.	Flow through velocity, m/s	0.2-0.8	0.10-0.30
4.	Power required, Watt/m^3/hr	0.5-1.5	N/A
4.	Head loss, m of water	N/A	0.15-0.60

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.20: Relative Ratings of Mechanical and Non-mechanical Flocculation Units

	Description	Mechanical	Non-mechanical
1.	Efficiency with variable influent quality	10	4
2.	Effectiveness on small scale	B	B
3.	Effectiveness on big works	B	D
4.	Advantageous use of land	B	E

5.	Skilled person requirement	8	4
6.	Overall cost	8	4
7.	Extent of use	8	4

Note: For rating levels and abbreviations please refer to section 4.4.

9.4.1 Mechanical Flocculation

Inline Blender: Use this option for selecting inline blender flocculation unit. It consists of a rotating shaft with blades in the passage of water. It is similar to rapid mix unit. The only difference is in the speed of the shaft. In this unit there is minimum of short circuiting. It is less expensive than paddle and flat blade turbine.

Paddle Type Flocculator: Use this option for selecting paddle type flocculation units. The paddle type devices are mounted horizontally or vertically and rotate at low speeds 2 to 15 RPM. The currents generated are both radial and tangential.

Flat Blade Turbine Flocculator: Use this option for selecting flat blade turbine type flocculation unit. In this unit flat blades are connected to a shaft. The flat blades are in the same plane as the drive shaft. The blades can be mounted vertically or horizontally and operate at 10 to 15 RPM. This unit is least effective than above two units.

The Comparative performance considering various aspects of the "mechanical flocculation units" option, as included in the "performance" and "compare" advice options, is presented in Table 9.21.

Table 9.21: Comparative Performance of Inline, Paddle and Turbine Type Flocculator

	Description	Inline	Paddle	Turbine
1.	HRT, s	5-20	10-40	10-40
2.	Velocity Gradient, /s	35-66	10-75	35-66
3.	Flow through Velocity, m/s	0.3-0.9	0.2-0.8	0.3-0.9
4.	Power required, KW/MLD	6-25	10-36	6-30
5.	Shaft speed, RPM	2-10	2-15	5-10

Note: For rating levels and abbreviations please refer to section 4.4.

9.4.2 Non Mechanical Flocculation

Baffled Flocculator: Use this option for selecting baffled units for flocculation. In this option vertical baffle and horizontal baffled are implemented. Baffled plates can be of steel, wood or concrete. Velocity gradients are purposely intensified by enforced changes in the direction of flow. It is a simple system but is not flexible and involves much loss of head. The detention period is also restricted as otherwise long channels are required. These units are recommended for flow up to 200 m^3/h.

Gravity Flocculator: Choose this option for gravity flocculation unit from the options stone medium and floc module.

The Comparative performance and relative ratings considering various aspects of the "non-mechanical flocculation units" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.22 and 9.23 respectively.

Table 9.22: Comparative Performance of the Baffled and Gravity Flocculation Units

	Description	Baffled	Gravity
1.	HRT, sec	10-20	10-35
2.	Velocity gradient, /s	20-75	10-100
3.	Flow through velocity, m/s	0.10-0.30	0.05-0.45
4.	Head loss, m of water	0.15-0.60	0.10-1.2

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.23: Relative Ratings of the Baffled and Gravity Flocculation Units

	Description	Baffled	Gravity
1.	Efficiency with variable influent quality	4	4
2.	Effectiveness on small scale	B	B
3.	Effectiveness on big works	D	E
4.	Advantageous use of land	E	C
5.	Freedom from manufacturers patents	A	D
6.	Skilled person requirement	6	6

7.	Overall cost	6	6
8.	Extent of use	6	2

Note: For rating levels and abbreviations please refer to section 4.4.

Baffled flocculation can be of two types depending upon the orientation of the baffles as follows.

Vertical Baffled Flocculation: Use this option for selecting vertical baffled unit for flocculation. Velocity gradients are purposely intensified by enforced changes in the direction of flow upwards and downwards alternatively. In this unit a homogeneous mixture of the suspended particles is maintained due to alternate rise and fall of water, which prevents deposition of sludge. The direction of flow is the only significant difference between these two types, their advantages and disadvantages are virtually the same.

Horizontal Baffled Flocculation: Use this option for selecting horizontal unit for flocculation. It consists of series of baffles around the ends of which the flowing water is reversed in direction, thus causing turbulence and agitation at each point of reversed flow. Proper scouring arrangements have to be made in this unit to prevent deposition of sludge.

The Comparative performance and relative ratings considering various aspects of the "baffled flocculation units" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.24 and 9.25 respectively.

Table 9.24: Comparative Performance of Vertical and Horizontal Baffled Flocculation Units

	Description	Vertical	Horizontal
1.	HRT, sec	10-20	15-20
2.	Velocity gradient, /s	10-100	10-100
3.	Flow through velocity, m/s	0.1-0.2	0.1-0.3
4.	Head loss, m of water	0.15-0.6	0.15-0.60

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.25: Relative Ratings of the Vertical and Horizontal Baffled Flocculation Units

	Description	Vertical	Horizontal
1.	Efficiency with variable influent quality	4	4
2.	Effectiveness on small scale	B	B
3.	Effectiveness on big works	D	D
4.	Advantageous use of land	E	E
5.	Freedom from manufacturers patents	A	A
6.	Skilled person requirement	6	6
7.	Overall cost	6	6
8.	Extent of use	4	8

Note: For rating levels and abbreviations please refer to section 4.4.

9.5 Softening

Chemical Softening: Select this option for design of chemical softening units. In this option chemical dose is calculated and thereafter rapid mix, flocculation and sedimentation units are designed. Select this option if water contains hardness greater than 500 mg/l and/or turbidity, color, and iron salts because these have tendency to foul the ion-exchange resins by coating on the granules. Chemical softening cannot reduce the hardness of water to less than 40 mg/l while ion-exchange softening can produce water with less hardness. This can be used as pre-treatment unit for waters having high hardness to be used for industrial use.

Ion Exchange Softening: Use this option for design of ion exchange softening unit. This process can produce almost zero hardness water. However, the total dissolved solids are not reduced. It is generally used as polishing unit after chemical treatment.

The Comparative performance and relative ratings considering various aspects of the "rapid mix units" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.26 and 9.27 respectively.

Table 9.26: Comparative Performance of Chemical and Ion-exchange Softening

	Description	Chemical	Ion Exchange
1.	Effluent calcium hardness as $CaCO_3$, mg/l	40-100	0-10
2.	Effluent magnesium hardness as $CaCO_3$, mg/l	10-30	0-5
3.	Operating pH	4-8	6.5-8.0
4.	Influent hardness as $CaCO_3$, mg/l	100-5000	Less than 500

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.27: Relative Ratings of Chemical and Ion-exchange Softening

	Description	Chemical	Ion Exchange
1.	Efficiency with turbid water	10	2
2.	Efficiency with low pH water	2	8
3.	Efficiency with water containing iron and manganese	8	2
4.	Production of zero hardness water	2	10
5.	Suitability for domestic water supply	B	C
6.	Suitability for industrial water supply	D	A
7.	Removal of total dissolved solids	8	0
8.	Efficiency in variable influent quantity	4	8
9.	Skilled person requirement	4	8
10.	Overall cost	4	8
11.	Extent of use	8	4

Note: For rating levels and abbreviations please refer to section 4.4.

9.6 Filtration

Slow Sand Filter: Use this option for design of slow sand filter unit. This unit consists of a water tight basin containing a layer of sand 75 to 90 cm thick, supported on a layer of gravel 20 to 30 cm thick. The gravel is underlain by a system of under drain pipes which lead the water to a single point of outlet where a device is located to control the rate of flow through the filter. After some interval the top layer of sand is

scraped and either washed and reused or wasted. Treatment in this unit requires minimum skill in operation.

High Rate Filter: Use this option for design of high rate filter units. Water should receive pre-treatment before passing through this unit. The water flows down the filters under gravity. The filtration medium can be single, dual or multi underlain by gravel. The filtration materials are natural silica sand, crushed anthracite, crushed magnetite and garnet sands. After some time the filter is back washed and entrapped material is washed away. This unit requires less space than slow sand filter and is suitable for large plants. However, treatment in this unit requires skilled supervision for operation.

Pressure Filter: Choose this option for design of pressure filters from the available options of single, dual and multi media. These units are based on the same principle as high rate gravity filters. However, water is passed through a cylindrical tank usually made of steel or cast iron where the under drain gravel and sand are placed. They are compact and can be pre-fabricated and moved to site. Economy is possible in smaller plants. Pre-treatment is essential. The tank axis may either be vertical or horizontal.

The Comparative performance and relative ratings considering various aspects of the "filtration" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.28 and 9.29 respectively.

Table 9.28: Comparative Performance of Slow Sand, High Rate and Pressure Filters

	Description	Slow Sand	High Rate	Pressure
1.	Depth of filter media, m	0.8-1.0	0.6-0.75	1.5-1.7
2.	Filtration rate, m/hr	0.1-0.2	4.8-6.0	7.2-18.0
3.	Effective size of filter media, mm	0.2-0.3	0.45-0.70	NA
4.	Uniformity coefficient of filter media	3-5	1.3-1.7	NA
5.	Standing water depth over filter bed, m	0.5-2.0	1.0-3.0	1.0-7.0
6.	Head loss, m of water	0.5-1.5	1.0-2.5	1.0-5.0

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.29: Relative Ratings of Slow Sand, High Rate and Pressure Filters

	Description	Slow Sand	High Rate	Pressure
1.	Efficiency in variable effluent quality	8	6	6
2.	Effectiveness on small scale	A	B	A
3.	Effectiveness on big works	D	A	C
4.	Advantageous use of land	E	C	A
5.	Freedom from manufacturers patents	B	D	E
6.	Skilled person requirement	2	6	8
7.	Overall cost	4	6	8
8.	Extent of use	6	6	2

Note: For rating levels and abbreviations please refer to section 4.4.

9.7 Disinfection

Pre Disinfection: Use this option for design of chlorination, ozonation and ultraviolet disinfection units just after pre-settling. The point of application as well as the dosage of disinfectant is controlled by the objectives i.e. control of biological growth in raw water conduits, promotion of improved coagulation, prevention of mud balls and slime formation in filters, reduction of tastes, odor and color and minimizing the post disinfection dose when dealing with heavily polluted water.

Post Disinfection: Use this option for design of chlorination, ozonation and ultraviolet disinfection units after any unit treatment process and prior to distribution to consumer. It is carried out to inactivate or control the microorganisms and pathogens in water which can adversely affect its quality or lead to disease from microbial activity.

9.7.1 Pre Disinfection

Chlorination: Use this option for design of pre-chlorination unit just after pre-settling. It controls biological growth in raw water conduits, promotes coagulation, prevents mud balls and slime formation in filters, reduce tastes, odor and color.

Ultraviolet Radiation: It is effective in inactivating all type of bacteria and viruses. The advantages are ready automation, no chemical handling, short retention time, no effect upon chemical characteristics and taste, low maintenance, no ill effect from over dosages. The disadvantages are lack of residual protection, relatively high cost, and need for low turbidity in the water to insure penetration of rays. The water being treated is made to flow in a thin film past a series of quartz mercury vapor arc lamps emitting ultraviolet light. This process is used primarily in industrial applications and private installations.

Ozonation: It is effective both in disinfection and reduction of tastes and odors. It is also effective as a germicide, in destruction of organic matters which might produce tastes or odors, and in oxidation of iron and manganese. The disadvantages which have restricted its use are its high cost relative to chlorination, the need to generate ozone at the point of use, and its spontaneous decay which prevents maintenance of residual in the distribution system.

The Comparative performance and relative ratings considering various aspects of the "pre disinfection" option, as included in the "performance" and "compare" advice options, are presented in Tables 9.30 and 9.31 respectively.

Table 9.30: Comparative Performance of Chlorination, UV Disinfection and Ozonation

	Description	Chlorination	Ultraviolet	Ozonation
1.	Contact time, min	10-30	-	1.0-2.5
2.	% kill achieved	99	99.99	99.99

Note: For rating levels and abbreviations please refer to section 4.4.

Table 9.31: Relative Ratings of Chlorination, UV Disinfection and Ozonation

	Description	Chlorination	Ultraviolet	Ozonation
1.	Efficiency in variable influent quantity	4	6	4
2.	Effectiveness in variable pH	E	A	C
3.	Residual disinfectant	8	2	2
4.	Odor additional problem	10	2	2
5.	Effectiveness in turbid water	C	E	E

6.	Effectiveness in small scale	B	B	B
7.	Effectiveness in big works	B	E	E
8.	Advantageous use of land	B	A	A
9.	Freedom from manufacturers patents	B	E	E
10.	Skilled person requirement	6	8	8
11.	Overall cost	4	8	8
12.	Extent of use	10	2	4

Note: For rating levels and abbreviations please refer to section 4.4.

9.7.2 Post Disinfection

Chlorination: Use this option for design of post-chlorination unit just after filtration. It permits residual levels and can protect from possible contamination during transport and distribution of water.

Ultraviolet Radiation: It is effective in inactivating all type of bacteria and viruses. The advantages are ready automation, no chemical handling, short retention time, no effect upon chemical characteristics and taste, low maintenance, no ill effect from over dosages. The disadvantages are lack of residual protection, relatively high cost, and need for low turbidity in the water to insure penetration of rays. The water being treated is made to flow in a thin film past a series of quartz mercury vapor arc lamps emitting ultraviolet light. This process is used primarily in industrial applications and private installations.

Ozonation: It is effective both in disinfection and reduction of tastes and odors. It is also effective as a germicide, in destruction of organic matters which might produce tastes or odors, and in oxidation of iron and manganese. The disadvantages which have restricted its use are its high cost relative to chlorination, the need to generate ozone at the point of use, and its spontaneous decay which prevents maintenance of residual in the distribution system.

9.8 Advance Processes

Ion Exchange: Use this option for design of ion exchange unit. In this unit a salt solution is percolated through a cation exchange resin treated with acids. The effluent contains equivalent amounts of corresponding acids. When this acidic effluent is passed through an anion exchange resin which has been treated with alkali, so that it contains replaceable hydroxyl ions, the anions are exchanged for the hydroxyl ions with the result that the effluent is rendered free from salts. It is possible by this unit to remove salts from saline/brackish water by use of percolation columns. The beds can be regenerated and used repeatedly without appreciable loss in capacity.

Desalination: Choose this option for selecting reverse osmosis and/or electro-dialysis for removing salts from water. These processes use semi permeable membranes to separate the solute from solvent. These membranes may be natural or synthetic.

9.8.1 Desalination

Reverse Osmosis: Use this option for design of reverse osmosis unit. It is a membrane permeation process for obtaining salt free water from saline/brackish water. The effluent raw water is passed over the surface of semi permeable membrane at a pressure in excess of the effective osmotic pressure of the influent water. The permeating liquid is collected as the product and concentrated influent solution is generally discarded. The membrane used is highly permeable to water but highly impermeable to the solutes and capable of withstanding the applied pressure without failure. Because of its simplicity in execution, reverse osmosis has considerable potential for water treatment.

Electrodialysis: Use this option for design of electro dialysis unit. It is also a membrane permeation process aided by the electromotive force. A number of electrolytic cells are arranged in series. The cells are composed of three compartments separated from each other by suitable membranes. The saline water circulates in series through middle compartments of cells and undergoes purification. A direct current of 110-220 volts is employed. The electrodes are continuously wasted with treated water.

However, the membranes get badly damaged due to corrosion and scale formation. This process is adopted for waters containing less than 10000 mg/l of dissolved solids.

10

Advice – III: Wastewater Treatment System

The aim of wastewater treatment is to treat the liquid wastes originating from household or industries to such an extent that all nuisance creating impurities are removed and the waste can be disposed without creating any health hazard. In some cases after purification the wastewater can be recycled to the system again. The broad categories in which the entire treatment scheme can be classified are as follows.

Pretreatment: Pretreatment consists of separation of floating and suspended organic and inorganic material by physical processes such as a) screening by which materials larger in size than the openings of the screening device is strained out, and b) grit removal by which coarse particles of ash and other inert materials which have subsidence velocities substantially greater than those of organic putrescible solids are removed.

Primary Treatment: Primary treatment is advised when (i) wastewater contains significant amount of suspended, organic and some amount of inorganic solids which can be settled in 1 to 2 h, (ii) large hourly variation in both quality and quantity of wastewater, and (iii) wastewater to be treated is generated in a batch process.

Primary treatment of wastewater generally consists of unit processes such as sedimentation and equalization.

Secondary Treatment: Secondary treatment is preferred for treatment of wastewater having settleable colloidal and/or soluble organic matter which are biologically degradable. Usually it is selected after preliminary and primary treatment, if any.

Biological processes are used to convert the finely divided and dissolved organic matter in wastewater into flocculent settleable biological and inorganic solid that can be removed in the secondary sedimentation tank or retained in the biological reactor.

Tertiary Treatment: Tertiary treatment is employed for i) recycle of wastewater and ii) if wastewater is low in BOD/COD and contains colloidal suspended and dissolved solids, which can be precipitated.

Sludge Treatment: Choose this option to design sludge treatment units. Sludge generated during primary and secondary processes contains high amount of water. It also contains largely the substances responsible for the offensive character of untreated wastewater and are organic in nature. Sludge treatment is employed to reduce the water and organic content of sludge and render it suitable for final disposal or reuse. The various alternatives available in sludge treatment are sludge thickening, sludge digestion, sludge dewatering and sludge disposal.

10.1 Pretreatment

Screening: Screen is a device with openings generally of uniform size for removing bigger suspended or floating matters in sewage. The screening element may consists of parallel bars, rods, gratings or wiremeshes or perforated plates and the opening may be of any shape, although generally circular or rectangular. Screen may be coarse, medium or fine. Screens are used ahead of pumping stations, meters and as a first step in all treatment works.

Grit Chamber: Grit chambers are designed to remove grit consisting of sand, gravel, cinders or other heavy solid materials that have subsiding velocities or specific gravities substantially greater than those of the organic putrescible solids in wastewater. They are most commonly located after the bar racks and before the primary clarifier.

Grit chambers are provided to (i) protect moving mechanical equipment from abrasion and accompanying abnormal wear and tear, (ii) reduce formation of heavy deposits in

pipelines, channels and conduits, (iii) Reduce the frequency of digester cleaning caused by excessive accumulation of grit.

There are three general types of grit chambers : Horizontal flow, Aerated or Vortex type.

Skimming Tank: Skimming tanks are employed for removing oil and grease from the sewage, and placed before the sedimentation tanks. They are used where sewage contains too much of grease or oils, which include fats, waxes, soaps, fatty acids, etc. These oily and greasy materials may be removed in a skimming tank, in which air is blown by an aerating device through the bottom. The rising air tends to coagulate and congeal the grease, and cause it to rise to the surface, from where it is removed.

If these greasy and oily materials are not removed from the sewage before it enters further treatment units, it may form unsightly and odorous scum on the surface of settling tanks, or interfere with the activated sludge process, and inhibit biological growth on the trickling filters.

Equalization Chamber: Flow equalization is used to overcome the operational problems caused by flow rate variations, to improve the performance of the downstream processes and to reduce the size and cost of downstream treatment facilities. It may be provided before or after the primary clarifier, but is preferred after the primary clarifier.

Flow equalization simply is the damping of flow rate variations so that a constant or nearly constant flow rate is achieved. Flow equalization results in i) enhanced biological treatment due to minimization of shock loading and ii) the effluent quality and thickening performance is improved through constant solid loading.

10.1.1 Grit Chamber

Horizontal Flow Grit Chamber: In this type of grit chamber the flow passes through the chamber in a horizontal direction and the straight line velocity of flow is controlled by the dimension of the unit, special influent distribution gates and the use of special weir sections at the effluent end.

Aerated Grit Chamber: The aerated grit chamber consists of a spiral flow aeration tank where the spiral velocity is induced and controlled by the tank dimension and quantity of air supplied to the unit. Amount of air controls spiral velocity, which in turn affects the removal of grit particles.

Vortex Type Grit Chamber: The vortex type consists of a cylindrical tank in which the flow enters tangentially creating a vortex flow pattern, centrifugal and gravitational forces cause the grit to separate. It is a recent development in WW treatment and is suitable up to 0.3 m^3/s.

The relative ratings considering various aspects of the "grit chamber", as included in the "comparison" option, are presented in Table 10.1.

Table 10.1: Relative Ratings of the Horizontal Flow, Aerated and Vortex Flow Grit Chamber

	Description	Horizontal Flow Chamber	Aerated Grit Chamber	Vortex Chamber
1.	Land required	8	6	4
2.	Power required	2	6	8
3.	Capital cost	2	6	8
4.	Operation and maintenance cost	2	8	8
5.	Reliability	B	C	D
6.	Odor problem	4	2	0

Note: For rating levels and abbreviations, please refer to section 4.4.

10.1.2 Equalization Chamber

On-Line Equalization: It causes considerable dampening of BOD/COD/TSS and other inhibiting substances. It is preferred when the mass loading variations are large in small time intervals and downstream units are susceptible to shock loads.

Off-Line Equalization: It causes slight dampening of BOD/COD/TSS and other inhibiting substances. It is preferred when the mass loading variations are small in considerable time and downstream units in treatment chain are relatively more shock resistant.

10.2 Primary Treatment

Equalization Chamber: Flow equalization is used to overcome the operational problems caused by flow rate variations, to improve the performance of the downstream processes and to reduce the size and cost of downstream treatment facilities. It may be provided before or after the primary clarifier, but is preferred after the primary clarifier.

Flow equalization simply is the damping of flow rate variations so that a constant or nearly constant flow rate is achieved. Flow equalization results in i) enhanced biological treatment due to minimization of shock loading and ii) the effluent quality and thickening performance is improved through constant solid loading.

Sedimentation: The purpose of sedimentation of sewage is to separate the settleable solids so that the settled wastewater, if discharged into water courses, does not form sludge banks and when used for land disposal does not lead to the clogging of soil pores and excessive organic loading.

Sedimentation is used in wastewater treatment to remove (i) Inorganic suspended solids or grit in grit chamber, (ii) organic and residual inorganic solids, free oil and greases and other floating materials in plain sedimentation, (iii) bio-flocculated solids or bio-flocs from effluent of secondary biological treatment units such as ASP etc, (iii) chemical flocs produced during chemical coagulation and flocculation in secondary settling tanks.

Chemical Treatment: It is generally used in industrial wastewater treatment. In case of acidic or alkaline waste, alkali or acid treatment (Neutralization) is used to neutralize the waste.

Aeration: Select this option for aeration of water for following reasons (i) to add oxygen to water for imparting freshness, (ii) to expel Carbon Dioxide, Hydrogen Sulfide and volatile substances (mainly organics) causing taste and odor, (iii) To precipitate impurities like Iron and Manganese.

The comparative performance evaluation considering various aspects of the "primary treatment" option, as included in the "performance" advice option, is presented in Table 9.2.

Table 10.2: Comparative Performance of Equalization, Sedimentation, Chemical Treatment and Aeration

	Description	Equalization	Sedimentation	Chemical	Aeration
1.	TSS removal %	N/A	40-70	NA	NA
2.	BOD removal %	N/A	30-40	NA	NA
3.	COD removal %	N/A	30-40	NA	NA
4.	Nitrogen removal %	N/A	5-15	NA	NA
5.	Phosphorous removal %	N/A	5-15	NA	NA
6.	Coliform removal %	N/A	5-25	NA	NA

Note: For rating levels and abbreviations, please refer to section 4.4.

10.2.1 Equalization Chamber

On-Line Equalization: It causes considerable dampening of BOD/COD/TSS and other inhibiting substances. It is preferred when the mass loading variations are large in small time intervals and downstream units are susceptible to shock loads.

Off-Line Equalization: It causes slight dampening of BOD/COD/TSS and other inhibiting substances. It is preferred when the mass loading variations are small in considerable time and downstream units in treatment chain are relatively more shock resistant.

10.2.2 Sedimentation

Rectangular Sedimentation Tank: It is difficult to construct and analyze structurally. Sludge scrapers require arrangement of adjustable arms to reach corner points of tank. Multiple unit construction may lead to economy due to common walls. For same area it gives less weir loading than circular shaped settling tanks.

Circular Sedimentation Tank: It is easy to construct and analyze structurally. Simple sludge scrapers are required. It may not be economical in case multiple units are required. The circular clarifiers may be of two types i) radial flow and ii) circumferential flow.

For comparative performance and relative ratings, please refer to Tables 9.7 and 9.8 respectively.

Circular clarifiers can be of two types depending upon the flow pattern as follows.

(i) Radial Flow: Influent is fed through the center and flow approaches horizontal flow. Effluent is collected by effluent launder at circumference.

(ii) Circumferential Flow: Influent enters through bottom of rim at circumference of the tank and effluent is collected at top of rim at circumference of the tank. The flow approaches to vertical flow.

For comparative performance and relative ratings, please refer to Tables 9.9 and 9.10 respectively.

10.2.3 Aeration

Diffused Aeration: Use this option for design of diffused aeration system with nozzle diffusers. This unit consists of nozzles and pipes in a basin in which compressed air is injected to rise through water being aerated. As the rising bubbles of air have a lower average velocity than the falling of drops, this unit provides a longer aeration period than the cascade type for the same head loss. These have higher initial costs and

require greater recurring expenditure. They require less space than spray aerators and cold weather working problems are not encountered. It is less popular in water treatment plant in comparison to other options.

Cascade Aeration: Use this option for design of cascade aerator in which water is allowed to flow downwards in a series of falls to produce turbulence. It adds to the beauty of plant. Head loss is greater than other options. In cold climates these aerators must be housed width adequate provision for ventilation. Corrosion and slime problem may be encountered in aerated water.

Spray Aeration: Use this option for design of spray aeration system in which water is sprayed through nozzles upward into the atmosphere in the form of fountain and broken up into either mist or droplets. Water is directed at a slight inclination to the vertical. The installation consists of trays and fixed nozzles on a pipe grid with necessary outlet arrangements.

The comparative performance and relative ratings considering various aspects of the "aeration" option, as included in the "performance" and "comparison" advice options, are presented in Tables 10.3 and 10.4 respectively.

Table 10.3: Comparative Performance of Diffused, Cascade and Spray Aeration System

	Description	Diffused	Cascade	Spray
1.	Carbon Dioxide removal %	40-75	20-45	70-90
2.	Hydrogen Sulfide removal %	50-80	20-35	90-99
3.	Volatile organic removal	NA	NA	NA
4.	Precipitation of Iron	NA	NA	NA
5.	Pressure required at nozzles (m of water)	5	N/A	7
6.	Precipitation of Manganese	NA	NA	NA
7.	Aerator area, m^2/KLD	N/A	0.50-0.65	0.00125-0.00375
8.	Air required m^3/KL	0.6-1.5	N/A	N/A

9.	Head loss (m of water)	N/A	0.5-0.30	8-10
10.	Power required W/KL	3-10	N/A	N/A

Note: For rating levels and abbreviations please refer to section 4.4.

Table 10.4: Relative Ratings of the Diffused, Cascade and Spray Aeration System

	Description	Diffused	Cascade	Spray
1.	Gas Transfer Efficiency	6	4	8
2.	Efficiency in cold climate	8	2	4
3.	Freedom from manufacturers patents	E	B	D
4.	Skilled person requirement	4-6	2	4-6
5.	Initial cost	8	4-6	6-8
6.	Maintenance cost	8	2-4	4-6
7.	Extent of use	2	6	8

Note: For rating levels and abbreviations please refer to section 4.4.

10.3 Secondary Treatment

Aerobic Process: In aerobic processes, the microbial assimilation of organic matter takes place in the presence of oxygen. These processes are high energy consuming processes and also produce more sludge per unit mass of organic load assimilated. But the sludge produced is less harmful in comparison to that produced from anaerobic processes.

The aerobic processes may be further classified into two groups depending upon the type of growth of microbes. The suspended growth system is one in which the microbes grow in a suspended solution, while attached growth systems are those in which the microbes grow on inert media. Activated sludge process and trickling filters are the respective examples of suspended growth and attached growth system.

Anaerobic Process: Anaerobic treatment of wastewater has a number of advantages over aerobic treatment processes, namely, the energy input of the system is low, as no energy is required for oxygenation, lower production of excess sludge per unit mass of organic matter stabilized, lower nutrient requirement due to lower biological

synthesis and the degradation of waste organic material leads to the production of bio-gas which is a valuable source of energy.

The comparative performance and relative ratings considering various aspects of the "secondary treatment processes" option, as included in the "performance" and "comparison" advice options, are presented in Tables 10.5 and 10.6 respectively.

Table 10.5: Comparative Performance of Aerobic and Anaerobic Processes

	Description	Aerobic Processes	Anaerobic Processes
1.	TSS removal %	75-95	60-80
2.	BOD removal %	70-98	60-80
3.	COD removal %	70-98	60-80
4.	Nitrogen removal %	25-98	10-30
5.	Phosphorous removal %	25-98	10-30
6.	Coliform removal %	75-99	50-85

Note: For rating levels and abbreviations please refer to section 4.4.

Table 10.6: Relative Ratings of the Aerobic and Anaerobic Processes

	Description	Aerobic Processes	Anaerobic Processes
1.	Organic load	6	10
2.	Land required	4-10	4-10
3.	Power required	0-10	2-4
4.	Capital cost	4-10	6-8
5.	Operation and Maintenance cost	2-10	4-6
6.	Reliability	2-8	6-8
7.	Resistance to shock loads	D	C
8.	Sludge treatment	2-8	4-6
9.	Odor problem	2	4

Note: For rating levels and abbreviations please refer to section 4.4.

10.3.1 Aerobic Process

Activated Sludge Process: Activated sludge process is a suspended growth aerobic process. In this process sewage containing waste organic matter is aerated in an aeration basin in which, microorganisms metabolize the soluble and suspended organic matter. Part of the organic matter is synthesized into new cells and rest is oxidized to carbon dioxide and water to derive energy. The new cells formed in the reaction are removed from the liquid stream in the form of flocculent sludge in the settling tank. A part of this activated sludge is recycled to the aeration basin and the remaining forms waste or excess sludge.

Activated sludge process is capable of handling most of the wastewater. It is the most mechanized, requires construction vigilance and skilled operation, hence costlier. Though highly sensitive, it is the most efficient process in treatment. Preferred for medium to large flow.

Oxidation Ditch: Oxidation ditch is a process modification of activated sludge process. It consists of a ring or oval shaped channel and is equipped with mechanical aeration devices. Screened wastewater enters the ditch, is aerated, and circulated at about 0.25-0.35 m/s. Oxidation ditches typically operate in an extended aeration mode with long detention and solid retention times. Secondary sedimentation tanks are used for most applications.

Simple construction and operation and low sludge production are its merit over activated sludge process. Preliminary and primary treatment options can be omitted. It has higher power cost than activated sludge process but most reliable for moderate flows.

Aerated Lagoon: Aerated lagoons are similar to activated sludge process in terms of working principle. The major difference between activated sludge systems and aerated lagoon is that in the latter settling tanks and sludge recirculation are absent.

Aerated lagoons are generally provided in the form of simple earthen basin with inlet at one end and the outlet at the other to enable the wastewater to flow through while aeration is usually provided by mechanical means to stabilize the organic matter.

Aerobic lagoons are fully aerobic from top to bottom as the aeration power input is sufficiently high to keep all the solids in suspension besides meeting the oxygenation

demand of the system. No settlement occurs in such lagoons and under equilibrium condition the new microbial solids produced in the system equals the solid leaving the system. The solid concentration in the effluent is relatively high and some further treatment is generally provided after such lagoons.

Facultative Lagoon: Facultative lagoons are those in which some solids may leave with the effluent stream and some settle down in the lagoon. Since aeration power input is just enough for oxygenation and not for keeping all solids in suspension, the lower part of such lagoons may be anoxic or anaerobic, while the upper part is aerobic.

Trickling Filter: Trickling filters are used for complete treatment of moderately strong wastes and as roughing filters for very strong wastes prior to activated sludge units. They handle shock loads and provide dependable performance with a minimum of supervision.

The trickling filter consists of a permeable bed of medium through which the sewage is allowed to percolate. The materials used are filter medium include crushed or broken rock, gravel blast furnace slag or inert synthetic materials such as plastics and ceramics. Randomly packed solid media like rock, gravel and slag are characterized by lower porosity (40-60%), lower specific surface areas (40-70 m^2/m^3) and are much deeper (upto 12 m). Compared to conventional filters. Filters using plastic media are operated at much higher hydraulic and Organic Loading Rates.

The trickling filters are generally circular. They are generally preceded by primary settlement, so that the solids in the sewage may not clog the filter.
Single stage units consists of a primary settling tank, the filter, secondary settling tank, and facilities for recirculation of the effluent.

Two stage filter consists of two filters in series with a primary settling tank an intermediate settling which may be omitted in certain cases and a final settling tank. The effluent from the first stage filter is applied on the second stage filter either after settlement or without settlement.

Oxidation Pond: Oxidation ponds are open, flow through earthen basins specifically designed and constructed to treat sewage and biodegradable industrial wastes. They

provide comparatively large detention periods extending from a few to several days. During this period putrescible organic matter in the waste is stabilized in the pond through a symbiotic relationship between bacteria and algae.

Under many situations in warm climate countries pond system are cheaper to construct and operate compared to conventional methods. They did not require skilled operational staff and their performance do not fluctuate from day to day. But it requires relatively large land.

Aerobic ponds are designed to maintain completely aerobic conditions. They are used for soluble wastes, which allow penetration of light throughout the liquid depth. The ponds are kept shallow with depth less than 0.5 m, and may be periodically mixed. Such ponds develop intense algae growth and have been used on experimental basis only. The supernatant quality is poor in comparison to facultative pond's effluent.

Aerobic ponds are suitable for nutrient removal and treatment of soluble biodegradable organic matters. It is also sometimes as the polishing unit for effluent from activated sludge/trickling filter/UASB. Lower organic loading is possible and it requires very large land.

Facultative Pond: The facultative pond functions aerobically at the surface while anaerobic conditions prevail at the bottom. The aerobic layer acts as a good check against odor evolution from the pond. The treatment effected by this type of pond is comparable to that of conventional secondary treatment processes.

Facultative ponds require lesser area than aerobic pond except strength to be treated – which can be little higher than that for ponds – and where power and operation costs are low.

The comparative performance and relative ratings considering various aspects of the "aerobic process" option, as included in the "performance" and "comparison" advice options, are presented in Tables 10.7 and 10.8 respectively.

Table 10.7: Comparative Performance of Various Aerobic Biological Processes

	Description	ASP	TF	AP	FP	AL	FL	OD
1.	TSS removal	85-95	75-95	80-90	85-95	60-80	65-90	85-95
2.	BOD removal	85-95	70-95	90-95	95-97	80-90	85-95	95-98
3.	COD removal	85-95	70-95	90-95	95-97	80-90	85-95	95-98
4.	N removal	25-75	25-70	95-96	60-80	27-70	20-60	20-40
5.	P- removal	25-75	25-70	77-87	50-80	25-70	20-60	20-40
6.	Coliforms	90-96	60-90	90-95	95-98	90-95	90-95	90-96

Note: For rating levels and abbreviations, please refer to section 4.4.

Table 10.8: Relative Ratings of Various Aerobic Biological Processes

	Description	ASP	TF	AP	FP	AL	FL	OD
1.	Organic load	8	6	4	4	6	6	8
2.	Land required	6	6	10	8	7	7	8
3.	Power required	10	6	2	2	8	6	10
4.	Operation & Maintenance Cost	7	4	2	2	4	4	8
5.	Capital cost	8	8	4	4	6	6	8
6.	Resistance to shock loads	A	C	D	D	C	D	A
7	Sludge treatment	8	8	4	2	6	4	4

Note: For rating levels and abbreviations, please refer to section 4.4.

ASP – Activated Sludge Process; TF – Trickling Filter; AP – Aerobic Pond; FP – Facultative Pond; AL – Aerated Lagoon; FL – Facultative Lagoon; OD – Oxidation Ditch;

10.3.2 Anaerobic Process

Upflow Anaerobic Sludge Blanket (UASB): In the UASB process, the waste to be treated is introduced in the bottom of the reactor. The wastewater flow upward through a sludge blanket composed of biologically formed granules or particles.

Treatment occurs at the wastewater comes in contact with the granule or particles. The gases produced under anaerobic condition cause internal circulation, which helps in the formation and maintenance of the biological granules. The particles that rise to the top surface with gas, strike the bottom of the degassing baffles, which cause the attached gas bubbles to be released, while the degassed granules drop back to the surface of the sludge blanket.

Expanded Bed Reactors: The expanded or fluidized bed reactor incorporates an upflow reactor partly filled with sand or a low density carrier such as coal or plastic beads, which provides a very large surface area for growth of bio-film. Expanded bed reactors do not aim at complete fluidization and use a lower upflow velocity resulting in lesser energy requirement. Higher biomass concentration (15,000-40,000 mg/l) has been reported. Because of this higher biomass, the expanded bed process can be used for the treatment of municipal wastewater at a very short hydraulic retention time.

Fixed Film Reactors: In anaerobic fixed film reactor, the microbial mass is immobilized on fixed surfaces in the reactor. It is operated in downflow mode to prevent accumulation of refractory particulates contained in the influent and sloughed bio-film. The reactor packing is usually of modular construction consisting of plastic sheets providing a high void ratio. Such reactors have been constructed to treat high strength wastewater.

The comparative performance and relative ratings considering various aspects of the "anaerobic process" option, as included in the "performance" and "comparison" advice options, are presented in Tables 10.9 and 10.10 respectively.

Table 10.9: Comparative Performance of the UASB, Expanded Bed Reactor and Fixed Film Reactor

	Description	UASB	Expanded Bed Reactor	Fixed Film Reactor
1.	TSS removal	60-80	NA	NA
2.	BOD removal	60-80	NA	NA

3.	COD removal	60-80	NA	NA
4.	Nitrogen removal	10-30	NA	NA
5.	Phosphorous removal	10-30	NA	NA
6.	Coliforms removal	50-85	NA	NA

Note: For rating levels and abbreviations, please refer to section 4.4.

Table 10.10: Relative Ratings of the UASB, Expanded Bed Reactor and Fixed Film Reactor

	Description	UASB	Expanded Bed Reactor	Fixed Film Reactor
1.	Organic loading	8	10	6
2.	Land required	6	4	6
3.	Power required	4	8	4
4.	Capital cost	4	6	6
5.	Operation and maintenance cost	4	8	4
6.	Reliability	6	4	4
7.	Resistance to shock load	C	C	C
8.	Sludge treatment required	4	4	4
9.	Odor problem	4	4	4

Note: For rating levels and abbreviations, please refer to section 4.4.

10.4 Tertiary Treatment

Disinfection: Choose this option for design of disinfection units. Select this option for ensuring that pathogens and other microorganisms are inactivated. Bacteria, Viruses and Amoebic Cysts Constitute the three main types of human enteric pathogens and effective disinfection is aimed at destruction or inactivation of these and other pathogens such as helminths responsible for water borne diseases. The need for disinfection in ensuring protection against transmission of water borne diseases cannot be over emphasized and its inclusion as one of the water treatment process is considered necessary.

Clari flocculation: Use this option for combined coagulation, flocculation and settling.

Filtration: Choose this option for design of filtration units from the options slow sand, high rate and pressure. Use this option for separating out suspended and colloidal impurities from water by a passage through a porous bed. It is employed for treatment of water to effectively remove turbidity, color, microorganisms, precipitated hardness from chemically softened waters and precipitated Iron and Manganese from aerated waters. Select this option after flocculation and settling or softening and settling. Choose disinfection after this option.

Advance Processes: Use this option for production of ultra pure water and treatment of saline water. This option should be chosen after each of above options

10.4.1 Disinfection

Chlorination: Use this option for design of pre-chlorination unit just after pre-settling. It controls biological growth in raw water conduits, promotes coagulation, prevents mud balls and slime formation in filters, reduce tastes, odor and color.

Ultraviolet Radiation: It is effective in inactivating all type of bacteria and viruses. The advantages are ready automation, no chemical handling, short retention time, no effect upon chemical characteristics and taste, low maintenance, no ill effect from over dosages. The disadvantages are lack of residual protection, relatively high cost, and need foe low turbidity in the water to insure penetration of rays. The water being treated is made to flow in a thin film past a series of quartz mercury vapor arc lamps emitting ultraviolet light. This process is used primarily in industrial applications and private installations.

Ozonation: It is effective both in disinfection and reduction of tastes and odors. It is also effective as a germicide, in destruction of organic matters which might produce tastes or odors, and in oxidation of iron and manganese. The disadvantages which restricted its use are its high cost relative to chlorination, the need to generate ozone at

the point of use, and its spontaneous decay which prevents maintenance of residual in the distribution system.

The comparative performance and relative ratings considering various aspects of the "tertiary treatment" option, as included in the "performance" and "comparison" advice options, are presented in Tables 10.11 and 10.12 respectively.

Table 10.11: Comparative Performance of Chlorination, Ultraviolet and Ozonation

	Description	Chlorination	Ultraviolet	Ozonation
1.	Contact time, min	10-30	-	1.0-2.5
2.	% kill achieved	99	99.99	99.99

Note: For rating levels and abbreviations, please refer to section 4.4.

Table 10.12: Relative Ratings of Chlorination, Ultraviolet and Ozonation

	Description	Chlorination	Ultraviolet	Ozonation
1.	Efficiency in variable influent quantity	4	6	4
2.	Effectiveness in variable pH	E	A	C
3.	Residual disinfectant	8	2	2
4.	Odor additional problem	10	2	2
5.	Effectiveness in turbid water	C	E	E
6.	Effectiveness in small scale	B	B	B
7.	Effectiveness in big works	B	E	E
8.	Advantageous use of land	B	A	A
9.	Freedom from manufacturers patents	B	E	E
10.	Skilled person requirement	6	8	8
11.	Overall cost	4	8	8
12.	Extent of use	10	2	4

Note: For rating levels and abbreviations, please refer to section 4.4.

10.4.2 Filtration

Slow Sand Filter: Use this option for design of slow sand filter unit. This unit consists of a water tight basin containing a layer of sand 75 to 90 cm thick, supported on a layer of gravel 20 to 30 cm thick. The gravel is underlaid by a system of under drain pipes which lead the water to a single point of outlet where a device is located to control the rate of flow through the filter. After some interval the top layer of sand is scraped and either washed and reused or wasted. Treatment in this unit requires minimum skill in operation.

High Rate Filter: Use this option for design of high rate filter units. Water should receive pre-treatment before passing through this unit. The water flows down the filters under gravity. The filtration medium can be single, dual or multi underlaid by gravel. The filtration materials are natural silica sand, crushed anthracite, crushed magnetite and garnet sands. After some time the filter is back washed and entrapped material is washed away. This unit requires less space than slow sand filter and is suitable for large plants. However, treatment in this unit requires skilled supervision for operation.

Pressure Filter: Choose this option for design of pressure filters from the options available of single, dual and multi media. These units are based on the same principle as high rate gravity filters. However, water is passed through a cylindrical tank usually made of steel or cast iron where the under drain gravel and sand are placed. They are compact and can be pre-fabricated and moved to site. Economy is possible in smaller plants. Pre-treatment is essential. The tank axis may either be vertical or horizontal.

The comparative performance and relative ratings considering various aspects of the "filtration" option, as included in the "performance" and "comparison" advice options, are presented in Tables 10.13 and 10.14 respectively.

Table 10.13: Comparative Performance of Slow Sand, High Rate and Pressure Filters

	Description	Slow Sand	High Rate	Pressure
1.	Depth of filter media, m	0.8-1.0	0.6-0.75	1.5-1.7
2.	Filtration rate, m/hr	0.1-0.2	4.8-6.0	7.2-18.0
3.	Effective size of filter media, mm	0.2-0.3	0.45-0.70	NA
4.	Uniformity coefficient of filter media	3-5	1.3-1.7	NA
5.	Standing water depth over filter bed, m	0.5-2.0	1.0-3.0	1.0-7.0
6.	Head loss, m of water	0.5-1.5	1.0-2.5	1.0-5.0

Note: For rating levels and abbreviations, please refer to section 4.4.

Table 10.14: Relative Ratings of Slow Sand, High Rate and Pressure Filters

	Description	Slow Sand	High Rate	Pressure
1.	Efficiency in variable effluent quality	8	6	6
2.	Effectiveness on small scale	A	B	A
3.	Effectiveness on big works	D	A	C
4.	Advantageous use of land	E	C	A
5.	Freedom from manufacturers patents	B	D	E
6.	Skilled person requirement	2	6	8
7.	Overall cost	4	6	8
8.	Extent of use	6	6	2

Note: For rating levels and abbreviations, please refer to section 4.4.

The filtration process may be divided in two categories depending upon the filtration rate and mechanism as follows.

(i) High Rate Filtration

Single Media: Use this option for design of single media high rate filter unit. The water flows down the filter under gravity. The filtration medium used is sand.

Dual Media: The filtration medium consists of two different materials. The filtration materials available are natural silica sand, crushed anthracite, crushed magnetite and garnet sand. Generally sand is used over sand bed.

Multi Media: The filtration medium consists of more than two different materials. The filtration materials available are natural silica sand, crushed anthracite, crushed magnetite and garnet sand. Generally garnet sand is added below coal sand bed to construct multimedia filtration. Use of multimedia assures superior performance only if the materials used are properly sized.

(ii) Pressure Filtration

Single Media: Choose this option for design of single media pressure filter.

Dual Media: Choose this option for design of dual media pressure filter.

Multi Media: Choose this option for design of multimedia pressure filter.

10.4.3 Advance Processes

Adsorption: It is the process of collecting soluble substances that are in solution on a suitable interface. The interface can be between the liquid and a gas, a solid, or another liquid. In wastewater treatment adsorption on activated carbon is used as a polishing process for wastewater that has already received normal biological treatment. It removes the dissolved organics in wastewater that is left untreated in the earlier processes.

Ion Exchange: Use this option for design of ion exchange unit. In this unit a salt solution is percolated through a cation exchange resin treated with acids. The effluent contains equivalent amounts of corresponding acids. When this acidic effluent is passed through an anion exchange resin which has been treated with alkali so that it contains replaceable hydroxyl ions. The anions are exchanged for the hydroxyl ions with the result that the effluent contains equivalent amounts of corresponding acids.

When this acidic effluent is passed through an anion exchange resin which has been treated with alkali so that it contains replaceable hydroxyl ions, the anions are exchanged for the hydroxyl ions with the result that the effluent is rendered free from salts. It is possible by this unit to remove salts from saline/brackish water by use of percolation columns. The beds can be regenerated and used repeatedly without appreciable loss in capacity.

Desalination: Choose this option for selecting reverse osmosis or/and electro-dialysis for removing salts from water. These processes use semi permeable membranes to separate the solute from solvent. These membranes may be natural or synthetic.

10.5 Sludge Treatment

Sludge Thickening: Sludge thickening or dewatering is adopted for reducing the volume of sludge or increasing the solid concentration to (i) permit increased solid loading to sludge digesters, (ii) increase feed solids concentration to vacuum filters (iii) economize on transport cost (iv) minimize the land requirement as well as handling cost when digested sludge has to be transported to the treatment site, and (v) save the auxiliary fuel that may otherwise be needed when incineration of sludge is practiced.

Sludge Digestion: The principle purposes of sludge digestion are to reduce its putrescibility or offensive odour, pathogenic contents and to improve its dewatering characteristics. This can be achieved through any of the following biological processes – aerobic digestion and anaerobic digestion.

Sludge Dewatering: The digested primary or mixed sludge can be compacted to a water content of about 90 % in the digester itself by gravity, but mechanical dewatering with or without coagulant aids or prolonged drying on open sludge drying bed may be required to reduce the water content further. The dewatering of digested sludge is usually accomplished on sludge drying beds, which can reduce the moisture content to below 70 %.

10.5.1 Sludge Thickening

Gravity Thickener: It is the most common practice for concentration of sludge. This is adopted for primary sludge or combined primary and activated sludge, but is not successful in dealing with activated sludge independently. They are either continuous flow or fill and draw type with or without addition of chemicals. Use of slowly revolving stirrers improves the efficiency.

Dissolved Air Flotation: Dissolved air flotation process is primarily used to thicken the solids in chemical and waste activated sludge. Separation of solids is achieved by introducing fine air bubbles into the liquid. In this system the air is dissolved in the incoming sludge under a pressure of several atmosphere. The pressurized flow is discharged into a flotation tank that operates at one atmosphere. Fine air bubbles rise that cause the flotation of solids. The principle advantages of flotation over gravity thickening is the ability to remove more readily and completely those particles that settle slow under gravity. The amount of thickening achieved is 2-8 times the incoming solids.

Centrifugation: Centrifugation is a process by which solids are thickened or dewatered from the sludge under the influence of centrifugal field many times the force of gravity. Centrifugal thickening of sludge requires high power and high maintenance cost. Use should be limited to plants, where space is limited, skilled operation is available and sludge is difficult to thicken by other means.

The relative ratings considering various aspects of the "sludge thickening" option, as included in the "performance" and "comparison" advice options, are presented in Tables 10.15.

Table 10.15: Relative Ratings of Gravity Thickening, Dissolved Air Flotation and Centrifugation

	Description	Gravity Thickening	Dissolved Air Flotation	Centrifugation
1.	Land required	6	6	4
2.	Power required	4	8	6
3.	Capital cost	6	6	8
4.	O & M cost	2	8	6
5.	Reliability	8	4	6
6.	Odor problem	2	2	2

Note: For rating levels and abbreviations, please refer to section 4.4.

10.5.2 Sludge Digestion

Aerobic Digestion: It can be used for secondary tank humus or for a mixture of primary and secondary sludge but not for primary sludge alone. The major advantages of aerobic digester over the anaerobic digestion are (i) lower BOD concentration in digester supernatant, (ii) production of odourless and easily dewaterable biologically stable digested sludge, (iii) recovery of more basic fertilizer value in the digested sludge, (iv) lower capital cost, and (v) fewer operational problem.

Anaerobic Digestion: Anaerobic digestion is the biological degradation of organic matter in the absence of free oxygen. During this process, much of the organic matter is converted to methane, carbon dioxide and water and therefore the anaerobic digestion is a net energy producer. Since little carbon and energy remains available, to sustain further biological activity, the remaining solids in the sludge are rendered stable.

The relative ratings considering various aspects of the "sludge digestion" option, as included in the "comparison" advice option, are presented in Tables 10.16.

Table 10.16: Relative Ratings of the Aerobic Digestion and Anaerobic Digestion

	Description	Aerobic Digestion	Anaerobic Digestion
1.	Organic load	6	8
2.	Land required	8	6
3.	Power required	8	4
4.	Capital cost	8	6
5.	Operation & Maintenance cost	8	4
6.	Reliability	C	B
7.	Resistance to shock loads	8	8

Note: For rating levels and abbreviations, please refer to section 4.4.

10.5.3 Sludge Dewatering

Sludge Drying Beds: This method can be used in all places where adequate land is available and dried sludge can be used for soil conditioning. Where digested sludge is deposited on well drained bed of sand and gravel, the dissolved gases tend to buoy up and float the solids leaving a clear liquid at the bottom which drains through the sand rapidly. The major portion of the liquid drains off in a few hours after which drying commences by evaporation.

Filter Press: It is one of the most popular method of sludge dewatering. It consists of round or rectangular recessed plate which when pressed together form hollow chambers. On of the face of each individual plate is mounted a filter cloth. The sludge is pumped under high pressure into the chamber. The water passes through the cloth while the solids are retained and form a cake on the surface of the cloth. The solid contact of the sludge cake ranges from 20-40 %.

The relative ratings considering various aspects of the "sludge dewatering" option, as included in the "comparison" advice option, is presented in Tables 10.17.

Table 10.17: Relative Ratings of the Sludge Drying Beds and Filter Press

	Description	Sludge Drying Beds	Filter Press
1.	Land required	8	4
2.	Power required	2	6
3.	Capital cost	4	6
4.	Operation & Maintenance cost	2	4
5.	Odor problem	4	4

Note: For rating levels and abbreviations, please refer to section 4.4.

11 Epilogue

The present work was an attempt to develop a comprehensive software to serve as a tool in environmental engineering profession dealing with water supply and various pollution control measures. The software is aimed at assisting the practicing engineers as well as those associated with environmental engineering education and training. This work was essentially a task to compile, comprehend and supplement the information available through the various theses/project reports on software development at IIT Kanpur over the past decade on water treatment, wastewater treatment, local exhaust ventilation system, control of particulate and gaseous emissions.

The software developed includes four modules which incorporate apects related to air pollution control, water supply, liquid and solid waste management. The modules on air pollution control, water supply and wastewater management have been developed to a greater extent and includes several options which are fully implemented. The program code of this package is written in Turbo C and the graphics related to orthographic projections have been first developed in Auto CAD (ver 12.0) and then imported appropriately. The software structure is formulated in such a way that it allows flexibility in selection of options and also permits addition of modules and options in future. It runs through a master control program in MS DOS environment. The results have been validated through independent computations on several problems for most of the options which are completely implemented in this package.

However, any software package requires rigorous testing through various sets of input data to validate the operations performed. With this view in mind and to

fulfill the overall objectives following suggestions are made for logical continuation of the work presented in this thesis.

- The present work should be tested for different input data to assess the reliability and find out the bugs, if any, so that it can be removed.
- In present work cost estimate has not been included in the objectives. However, in future cost estimation may be attempted for all selected options.
- This software is executable in DOS environment. However, most of the commercial software available work in Windows environment, which provides better interface, user interaction, graphical presentation and look. Efforts may be done to link/transfer this package to Windows environment.
- The modules and options, such as solid waste management, water distribution system, sewerage system, waste disposal systems, atmospheric dispersion of pollutants, on which substantial information is already available, should be incorporated.

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